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GUIDELINES FOR ASSESSING SOIL LIMITATIONS FOR TRAILS IN THE SOUTHERN CANADIAN ROCKIES

by

© PHILIP FRANK EPP

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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OF MASTER OF SCIENCE

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graudate Studies and Research, for acceptance, a thesis entitled "Guidelines for Assessing Soil Limitations for Trails in the Southern Canadian Rockies" submitted by Philip Frank Epp in partial fulfilment of the requirements for the degree of Master of Science

ABSTRACT

The demand for outdoor recreation has been increasing rapidly and is expected to keep on increasing in the future. This demand has led to overuse of some existing facilities and has necessitated the construction of new facilities. Recently, there has been an increased awareness that soils information can be used to correctly plan and design recreation areas. As a result, soil surveys and biophysical inventories are now being carried out in many National and Provincial Parks in Canada.

This study evaluates the criteria which are presently used to make interpretations of soil limitations for trail use. The criteria are evaluated in Yoho, Banff, and Waterton Lakes National Parks in terms of influences on trail response, construction costs and management objectives. Differences in interpretations of criteria by various authors are emphasized during the tests.

Soil texture, gravel content, cobble content, stoniness, wetness, rockiness, slope and flooding are shown to be important considerations when assessing soil limitations for trail use. Aspect, position on slope, elevation and snow avalanching did not cause significant differences in trail response but may represent important management considerations. Landform, parent materials and vegetative habitat may provide useful site information, but this information is redundant when the above items are considered.

The results of the evaluations are incorporated in a table of refined guidelines for assessing soil limitations for trail use.

The assumptions on which the guidelines are based, instructions for use of the table, and an indication of the limitations of the interpretations are included with the table. Use of the guidelines as suggested should allow more reliable and useful interpretations of soil limitations for trails in the Canadian Rockies and elsewhere under similar environmental conditions.

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INTRODUCTION

Increased awareness of the applicability of soil survey information to recreational land use has led to soil surveys and bio-physical inventories being carried out in many of the National and Provincial Parks in Canada in recent years. A soil survey of Waterton Lakes National Park was carried out in 1972, the Revelstoke Summit area in Revelstoke National Park was soil surveyed in 1973, Yoho National Park was soil surveyed in 1973 and 1974 and a continuing biophysical inventory was begun in Banff and Jasper National Parks in 1974.

Recent experience in mapping soils in the mountain National Parks has indicated that the guidelines which are presently used in making assessments of soil suitability for recreational uses are often inadequate. As well, there are differences in the interpretation of the limits within the criteria as used by various authors. Thus, while useful interpretations of the soil survey information are presently being made, the interpretations are not as good as they could be. The present guidelines are also difficult to use for on-site evaluations by non-soils personnel.

Hiking trail use is a recreational use which occurs on a variety of soil map units showing a wide range of soil and site characteristics. For this reason, an evaluation of the interpretations for hiking trails is a good place to start an evaluation of the interpretive criteria.

The prime objective of this investigation is to evaluate the soil and site criteria which are interpreted as influencing soil use for trails, in terms of what is most suitable for use in the Parks in the

Rocky Mountains. The Parks in the Rocky Mountains were chosen for this study because of the large area (about 8,000 square miles) of Parks located here and also because of the author's experience with the soils in Yoho and Banff National Parks.

A secondary objective of this study was to make the guidelines more useable by laymen such as parks personnel for making site specific assessments of suitability.

The study was carried out in Yoho, Banff, and Waterton Lakes National Parks which lie adjacent to the Continental Divide in the Rocky Mountains in British Columbia and Alberta (Fig. 1). Yoho and Banff were selected because of the author's experience with soils in these areas and Waterton was added to give a wider range of environmental conditions.

Figure 1. Location of Study Areas.

LITERATURE REVIEW

Outdoor Recreation Demand and Its Consequences

The demand for outdoor recreation is increasing rapidly (Montgomery and Edminster, 1966). Population growth, economic affluence, increasing leisure time and greater mobility-accessibility have made outdoor recreation a more enjoyable and more desired experience for vastly larger numbers of people (Dooling, 1969; Brockman and Merriam, 1973). Along with the increase in numbers of people taking part in outdoor recreation as a whole, the number of people involved in hiking and walking for pleasure has also been growing rapidly and is expected to grow in the future (Lucas, 1971). This demand for outdoor recreation is placing extreme pressure on many recreation areas (Desmore and Dahlstrand, 1965). Increased demands for outdoor recreation must be met by developing more facilities, not by overcrowding and overusing those that already exist (Bohart, 1968).

Currently there is an unprecedented surge of interest and concern in meeting outdoor recreation needs (Udall, 1964), but in many areas, use already exceeds the capabilities of existing or proposed facilities (Dotzenko, Papamichos, and Romine, 1967). The most serious consequence of such pressures is one of deteriorating quality, expressed in both the physical and social carrying capacity of the sites (Wright, 1971). A current problem is gaining control of this situation and then giving direction to events rather than permitting events to take their own course (Dooling, 1969). Resource managers are now realizing that forest lands used for recreation have a specific carrying capacity for

people (Ketchledge and Leonard, 1970). Maintaining recreational use within the carrying capacity should be a primary objective (Bohart, 1968).

Applicability of Soils Information to Recreation Interpretations

Understanding the reasons why recreational areas deteriorate at different rates may lead to solutions of many problems concerned with the selection, development, maintenance and rehabilitation of intensely used areas and eliminate these problems from future use. Soil is a basic resource and therefore it is a key consideration in any form of land use (Dotzenko, Papamichos, and Romine, 1967).

That is not to say that soils are the only consideration in determining recreational potential, but they do influence both capability and capacity ratings (Dooling, 1969). Various kinds of soil react differently to varying degrees and intensities of use (Brockman and Merriam, 1973), so the kind of soil must have a high priority in the selection of sites for different recreational uses (Montgomery and Edminster, 1966; Bohart, 1968). Some of the soil properties which influence an area's usefulness or suitability for recreation are: texture, slope, permeability, drainage, flooding, bearing capacity, depth, and coarse fragment contents (Montgomery and Edminster, 1966; Bohart, 1968; Dooling, 1969).

The initial phase in the planning, the use and development of any resource is an inventory of the nature of the resource -- its kind, quality, quantity and distribution (Pluth, 1969). The location of soil boundaries, the delineation of soil areas on maps and their classification

is part of the soil survey process. Areas of a soil delineated on a map have properties that differ from those of other delineated soils (Lavkulich and Rowles, 1969), and different soils have different use capacities (Stevens, 1966). Thus, mapping soils separates the landscape into unique, homogeneous units that can serve as a basis for land use and management purposes (Lavkulich and Rowles, 1969). Soil surveys can provide some of the most useful criteria available to management for making properly designated and located recreation areas (Stevens, 1966).

Simply mapping the soils isn't enough, however. Specialists bear responsibility beyond supplying good data; they must also be willing to interpret it and to predict the consequence of various alternative actions. "We shouldn't start with specialists gathering all the information possible and then have decisionmakers wondering how to put it to use" (Feuchter and Wingle, 1973). The purpose of the soil interpretations is to provide people with the best information possible in a form that is directly useful to them (Aandahl, 1958).

Recognition of interpretations as an integral part of the soil survey began in about 1930, although some interpretations had been made before that time (Kellogg, 1961). The early interpretations were primarily for soil-agricultural crop relationships until after 1940 when interpretations of soils in relation to tree growth and in relation to engineering uses developed (Pluth, 1969). The Agricultural Rehabilitation Development Act of 1961 and subsequent establishment of the Canada Land Inventory Program provided impetus in Canada for systematic interpretations for several non-agronomic uses (Coen, 1973).

The systematic classification of land in Canada as to capability

for recreation was begun in 1965 (ARDA, 1965). The interpretations provided were general and were based on perceptual criteria as well as soils criteria. These interpretations are very useful when designating large areas as being generally suitable for recreation. In the National Parks, however, the initial designation of suitability for outdoor recreation has been carried out and what are needed now are guidelines for interpreting soil survey information for specific recreational uses.

Guidelines for interpreting soil survey information for various recreational uses were first published by Montgomery and Edminster and were based on early drafts by members of the United States Soil Conservation Service (Montgomery and Edminster, 1966). Guidelines were published for assessing limitations for camp areas, buildings in recreational areas, play areas, paths and trails, and picnic areas. (See Table 1 for guidelines for assessing soil limitations for paths and trails.) These guidelines provided for three degrees of limitation due to wetness, flooding, slope, surface texture, surface stoniness and rockiness, permeability, depth to bedrock, and coarse fragments. Only the first six soil characteristics mentioned were used in the evaluation of suitability for paths and trails.

Guidelines similar to those used by Montgomery and Edminster have also been used by Brocke (1970) in two Alberta Provincial Parks, by Coen and Holland (1976) in Waterton Lakes National Park, by Knapik and Coen (1974) in Revelstoke National Park, by Vold (1975) in Yoho National Park, by Deeg (1976) in Yoho National Park and have been used by Greenlee since 1971 in Alberta Provincial Parks. (See Appendix A for the above guidelines for assessing soil limitations for paths and trails.) These

Table 1. Table 4 from Montgomery and Edminster (1966).

Soil Limitations for Paths and Trails

Soil Items Affecting Use	Degree of Soil Limitation		
	None to Slight	Moderate	Severe
Wetness[1]	Well and moderately well drained soils with seasonal water table below 3 feet.	Well and moderately well drained soils subject to seepage or ponding and somewhat poorly drained soils. Seasonal water table 1 - 3 feet.	Poorly drained and very poorly drained soils.
Flooding[1]	Not subject to flooding during season of use.	Subject to occasional flooding. May flood 1 or 2 times during season of use.	Frequent flooding during season of use.
Slope[2]	0 - 15%	15 - 25%	25% +
Surface texture[3]	sl, fsl, vfsl, l.	sil, sicl, scl, cl, sc, ls.	sic, c, sand, and soils subject to severe blowing.
	Gravelly and non-gravelly.		All very gravelly, very cherty, very cobbly, very channery soils.
Surface stoniness or rockiness[4]	Classes 0, 1, and 2.	Class 3.	Classes 4 and 5.

1 Season of use should be considered in evaluating these items.

2 Soil erodibility is an important item to evaluate in rating this item. Some adjustments in slope range may be needed in different climatic zones.

3 In arid and subhumid climates some of the finer textured soils may be reduced one soil limitation class.

4 Based on definitions in Soil Survey Manual, pp. 217-221.

guidelines all follow the same format as those by Montgomery and Edminster, but there are additions and deletions of items affecting use as well as changes in the interpretation of the limitations imposed by various items.

The guidelines presented in the above studies and reports are used to rate the suitability of the map units for selected recreational uses. The ratings are usually presented in tabular form, with or without the limitations which contributed to the rating. The interpretations are given as predictions intended to provide information for wise planning decisions, not as recommendations for land use (Coen, Epp, and Holland, 1976). An example of using soil survey interpretations as part of the trail planning process is given by Deeg (1976). Deeg uses soil survey interpretations in conjunction with vegetation, faunal, and user experience evaluations to make trail location recommendations. This work shows the usefulness of soil survey interpretations and illustrates how they can be used.

Previous Trail Studies

The previous trail studies may be broken into two broad categories: trail use surveys which are studies of the numbers and kinds of trail users, and ecological impact studies which look at the effects of trail use on the environment and at trail deterioration.

Visitor Use Surveys

Comprehensive park planning begins with two sets of information: a knowledge of the natural resources of the park in question and an understanding of the public that uses that park (Thorsell, 1967). In

order to gain that understanding of the public, a number of trail use surveys have been carried out in recent years. These include studies in Waterton Lakes National Park (Thorsell, 1966; Nagy, 1973), Yoho and Banff National Parks (Thorsell, 1967; Trottier and Scotter, 1973, 1975; Vold, 1975) and Mt. Assiniboine Provincial Park in British Columbia (Gain and Swanky, 1975). These studies provide data concerning visitor profiles, the pattern and distribution of visitor use, visitor satisfactions, their conceptions of the parks and their opinions about management objectives. This type of knowledge is essential to proper decision-making pertaining to management of backcountry areas (Stankey, 1971). However, in terms of evaluating suitabilities from a soils point of view, only the visitor satisfactions are important. The reports of visitor satisfaction contained in these surveys indicate that some trail conditions are unsatisfactory. This shows that more care and attention should be given to soil characteristics when constructing new trails or rerouting old trails.

Environmental Impact Studies

A number of environmental impact studies have been carried out in recreational areas within the last five years. Included among these are studies which deal partially or exclusively with deterioration caused by hiking trails. The latter includes studies in the Banff area by Root and Knapik (1972) and Trottier and Scotter (1973, 1975); in Waterton Lakes National Park by Nagy (1973); in Mt. Assiniboine Provincial Park, British Columbia, by Roemer (1975); in the Madison Range in Montana by Dale (1973); and in the Selway-Bitterroot Wilderness of Idaho by Helgath (1974). These studies indicate how to measure trail deterioration

and attempt to assess the factors responsible for the deterioration.

Root and Knapik (1972) stated that a "trail was considered damaged if it was deeply rutted or markedly V-shaped; if it contained loose boulders, cobbles, stones, or roots from which soil had been trampled down or eroded; or if it contained deep mud or quicked ground which was churned by traffic. Multiple trails which converge to form a broad band of loose, vegetation-free soil were also considered as damaged." Four degrees of damage were recognized by Root and Knapik. Nagy (1973) also defined four degrees of damage ranging from nil to severe in similar general terms as those used by Root and Knapik. Five degrees of trail impact were recognized by Roemer (1975) with mucking, braiding, erosion, and deepening being the types of impact. The problem with all three of the above studies is that the limits for assessing the degree of damage or impact aren't provided. This makes comparisons among authors difficult and limits the reproducibility of the results. A trail which is considered damaged by one individual could appear perfectly useable to another. Qualitative terms such as slight, moderate and severe impact have limited value without more quantitative definitions.

Trottier and Scotter (1973, 1975), Dale (1973) and Helgath (1975) have proposed more quantitative methods of measuring trail detereoration. Trottier and Scotter's method consists of assigning a degree of impairment to each of five categories of trail condition and then adding up the five numbers to give a single rating number. A low rating indicates a trail in good condition while a high number shows a poor condition. The categories considered are width, depth, moisture regime, stones and roots, and walkability. Width and depth ratings are

defined in terms of actual measurements while workable definitions of the three qualitative factors are provided, so as to allow good reproducibility of results. Both Dale (1973) and Helgath (1975) use a cross-sectional area loss measurement to quantify trail deterioration. This involves taking depth measurements at intervals across the trail and then calculating the cross-sectional area lost. This approach is completely quantitative, but neglects muddiness, dustiness, and poor walkability due to cobbles, stones and roots. Thus, the method of Trottier and Scotter could be considered to be the 'best' method of evaluating trail condition. It does have the fault, though, that an unuseable condition could result through muddiness and walkability alone but the measured response in this case would only be medium. What is needed is an evaluation system which also overcomes this problem.

The results of the trail studies are presented in general and sometimes somewhat vague terms. Nagy (1973) found that the primary cause of trail damage was due to water eroding poorly designed and poorly located trails, and suggested that "imperfectly-drained soils, seepage or discharge areas, unstable slopes, and areas along water channels or water catchment basins would be avoided in proper trail location". Visitor use was not considered to be a major factor causing damage on most trails. Trottier and Scotter (1973) concluded that "erosion by runoff water, groundwater seepage or a high water table in spring is the most influential factor affecting trail condition in the Lake Louise area". In the Egypt Lakes area (Trottier and Scotter, 1975), poor trail condition was a function of bad location and lack of constructed treads. Erosion and wear along those trail sections traversing bogs, swamps, marshlands, and seeps compounded the problem. Trail

conditions in the Egypt Block were not considered to be the result of overuse. These three reports provide good inventories of present trail conditions but have limited value for predicting how soils will react to trail use. The only predictions gained from these reports is that steep trails are often subject to erosion and wet areas will not withstand trail use.

Roemer (1975) concluded that "comparison of impacts with single measured and observed site variables such as drainage, texture, slope gradient, organic matter and infiltration times do not show clear correlations, indicating complicated interactions with many factors, including use". Reasons given for mucking were "various combinations of poor drainage with or without seepage and temporary streams from snow-melt, a U-shaped trail profile and a high content of organic matter on the soil surface". Erosion was commonly caused by "combinations of U-shaped trail profiles, running water, direction of trail in relation to slope, and less commonly slope gradient". Braiding was considered to be "largely a consequence of other impact and of trail obstructions such as snow banks and wet areas", while deepening was found to occur "on those soils with soft surface layers, either rich in organic matter or lacking stones". A correlation was found between impact and parent material with very high susceptibility on "slopewash", high susceptibility on wet basal tills and lowest susceptibility on ablation till and similar well-drained tills. The time of snowmelt was identified as the most critical time with regard to impact. Correlations of trail impacts with present user numbers were found to be generally weak. Roemer does go one step further than the previous studies in that he does correlate his observations with his soil units and so makes

predictions of carrying capacity for the soil units within his study area. His predictions cannot be extrapolated to other areas, however, because they are based on the observed performance of map units rather than on soil variables. Roemer's results may also be summed up by saying that erosion occurs when water is channeled down a trail and that wet soil conditions lead to trail deterioration.

Helgath (1975) concluded "that vegetative habitat, landform, and trail slope factors importantly related to trail erosion. Aspect, elevation, use and parent material have variable relations and should be further examined". In her study, however, Helgath did not consider drainage as a factor. Thus, vegetative habitat probably correlates well with deterioration because it expresses wetness. Her correlation of landform with trail erosion might be questioned on the basis of her grouping all landforms into four categories which lumped radically different landforms such as streambanks and ridgetops together under Alluvial Erosional, and colluvial cones with flood plains under Alluvial Depositional. Texture or particle size which is a very important item to analyze when assessing erosion potential (Wischmeier, Johnson, and Cross, 1971) was also omitted from her study. Thus, Helgath's present results have little predictive value. The suggestion is made in her conclusions that biophysical units based on soils, vegetation, and landforms could be used as a basis for predictive units. This approach, as outlined by Helgath, runs into the same problems as the work by Roemer. That is, observations of trail condition must be made on a particular unit before a prediction can be made about that unit. Thus, if no trails cross one type of unit, then no predictions can be made. What is needed is interpretations based on the soil properties of the

map units, not on the map units themselves.

Root and Knapik (1972) conclude that wetness, trail orientation and trail slope are important in causing trail damage, but in addition, recognize that soils with high silt contents are highly susceptible to erosion by running water. Root and Knapik also present a number of recommendations for trail location to ensure that the driest sites are used and that water does not run down the trail. Predictions of limitations for trail use are provided for the soils in the area based on soil properties and observed response. The discussions of the soil factors limiting use are general, however, and no limits are set for making predictions in other areas.

Dale (1973) was concerned mainly with vegetation response to trail use, but his results do show, in contrast to the other results, that increasing trail use causes an increase in trail width. Dale found that a ten-fold increase from 1,000 to 10,000 visits per year had the effect of doubling trail width from 100 to 200 cm. This apparent contrast could be accounted for by the relatively low numbers of people using the trails in other areas (eg. a total of about 6,000 people used the trails in the Egypt Block, Banff, in 1974, indicating that the heaviest possible use on any trail was 6,000 people (Trottier and Scotter, 1975)) and by the fact that Dale looked at trails on less than 5 percent slopes where use could widen the trail, whereas most trails in the other areas are on relatively steep slopes which prohibit widening.

Summary of Previous Trail Studies

A number of trail studies have been carried out in recent years which assess visitor use and environmental impact caused by that use.

Methods are presented for assessing impact and several factors are cited as being responsible for that impact. There is general agreement that erosion occurs whenever trail design permits water to run down the trail and that wet conditions resulting from poor drainage, seepage, or late snowmelt at the time of use lead to trail deterioration. High silt contents, high organic matter contents, landforms, parent materials, and vegetative habitat have also been correlated with trail deterioration. There is some evidence that increasing trail use leads to increased trail widths, but most studies concluded that use did not contribute to the observed condition on good sites.

Trail Design

Trail planning and design is a process of asking and answering questions. The main questions concerned with trail development are "where" and "how"; where should the trail be located and how should it be built in order to meet the objectives of environmental preservation and user satisfaction (Parks Canada, 1975). The fact that this has not always been the case is illustrated by the statement by Deeg (1975) that in the past, "many trails have been built in an impromtu manner, with little or no consideration given to the proper location of trail route, the design of standards to meet those locations, the construction of the trail itself and its conformity to the natural environment. The result is that in any National Park, trails of both exceptionally high construction standard and quality of trail experience and other trails that present nightmares to even the most experienced hiker may be found." Poor location and design have also been implicated as the major sources

of trail deterioration in other studies (Nagy and Scotter, 1973; Trottier and Scotter, 1973, 1975).

An assessment of how good the trail location was must be based on trail objectives and alternatives. In some situations it may be necessary to route the trail through areas that do have poor soil conditions, either because alternative locations are unavailable or because it suits the particular needs of the trail (Parks Canada, 1975). In most cases, trail deterioration then becomes a function of inadequate design to meet the soil and site conditions of the chosen location.

Much has been written about the methods of good trail design including publications by Ashbaugh (1965), Vogel (1968), Root and Knapik (1972), Purych (1975), Parks Canada (1975), and Deeg (1976). Solutions to most soil related problems such as construction on steep slopes, wet areas or adverse textures are discussed in detail in these reports and as such will not be repeated here. It should be noted, however, that as soil and site conditions become more unsuitable, higher levels of design are required and the resulting construction costs increase.

Trail Standards

A consideration of the trail standards is important in the evaluation of soil suitabilities for trail use because trail standards are an important factor in determining construction difficulties. Trails may be built for a number of purposes and types of use and the trail standards vary accordingly (Ashbaugh, 1965; Purych, 1975; Parks Canada, 1975).

Thorsell (1969) stated that "ideally, the best trails should

have a cleared width of at least four feet and a tread width of from one to four feet. The grade should be to a maximum of 20 percent; rocks, roots and excessive vegetation should be removed and attention should be given to drainage patterns and erosion." Ashbaugh (1965) also recommends the use of cuts on hillsides in order to achieve level treads.

Parks Canada (1975) recognized three different sets of standards for wilderness backpacking trails, scenic hiking trails, and interpretive nature trails. The standards set for wilderness trails are similar to those used by Thorsell, but for scenic hiking trails and interpretive nature trails wider widths and lower grades were established to accommodate higher numbers of users as well as more diverse levels of users.

Nature trails will receive the highest intensity of use due to their accessibility and general shortness (usually 3/4 to 1 1/2 miles) and will also require the highest standards since people of all ages and all abilities will use them. Due to their shortness, however, high construction costs for special surfacing and tread levelling to meet the high standards should not be considered unreasonable.

Scenic hiking trails are intended as day-use trails and are also expected to be heavily used. The recommended maximum sustained trail grade is 5 to 8 percent with a short distance maximum of 18 percent. These trails may be built up to 180 cm wide. Wilderness backpacking trails are designed for overnight use and will be the most lightly used of all classes of trails. These trails may be built with sustained grades of up to 12 percent and grades of up to 20 percent for short distances. Trail widths will range from 45 to 120 cm.

Differences in standards among the classes of trails are

important from a construction cost point of view. Lower maximum sustained grades will result in more miles of trail being built when ascending or descending slopes. Similarly, clearing and construction costs are proportional to trail width. Thus, it is shown that trail construction difficulties will be proportional to trail standards and that a consideration of the standards to which a given trail is to be built is important in soil suitability evaluations.

General Description of the Study Area

Montgomery and Edminster (1966), when publishing their guidelines for assessing soil limitations for recreational uses, indicated that the limits of the criteria used in the evaluations might change for different major land resource areas, but that they should remain constant within the same land resource area. Brocke (1970) stated that the soil limitation groupings which he presented were applicable only in the areas he considered because the groupings were established with the particular environmental conditions of each park in mind. Vold (1975) suggested that the general ranges given for each soil property within each interpretive category for Yoho National Park might be applicable in the Canadian Rockies.

These statements show that environmental characteristics of an area may influence the interpretation of various soil criteria. Thus, a general description of the physiography, geology, climate, vegetation, and soils found within the study area is presented here so that the potential user may judge for himself the applicability of this author's work to the area in question.

Physiography and Topography

The portions of Yoho, Banff, and Waterton Lakes National Parks included in this study lie within the Rocky Mountain Area of the Eastern System of the Cordilleran physiographic region of Canada (Bostock, 1968). This area is characterized by high rugged mountain peaks and deep, relatively narrow valleys. The main valleys cutting across the mountains are the Kicking Horse Valley in Yoho, the Bow Valley in Banff, and the main valley containing the Waterton Lakes and the Belly River Valley in Waterton. Numerous smaller tributary valleys join the main valleys and often contain small clear lakes.

Elevations in the study area range from a low of 1,000 meters (3,300 feet) at the western edge of Yoho to more than 3,450 meters (11,300 feet) in the Continental Divide separating Yoho and Banff. The lowest elevation in the study area in Banff is at about 1,430 meters (4,700 feet) while the lowest elevation in the study area in Waterton is about 1,440 meters (4,750 feet).

Bedrock and Surficial Geology

The bedrock geology of the Mountain National Parks has been discussed at various levels of detail in a number of publications including: Allan (1914), Douglas (1952), MacKay (1952), North and Henderson (1954), Baird (1964), Douglas *et al.* (1968), Balkwill (1969), Cook (1970), Price and Mountjoy (1970), Aitken (1971), and Price (1971). This information may be summarized briefly as follows: the Rocky Mountains are underlain very largely by sedimentary and metamorphic rocks which range in age from Proterozoic to Cretaceous. Yoho and the portion of the study area in Banff are in the Main Ranges of the Rockies which are

characterized by thick cliff-forming limestone and quartzite formations interbedded with shale and slate formations. However, in the western half of Yoho National Park, shale and slate formations are dominant with minor interbedded limestone and dolomite formations. The portion of Waterton Lakes National Park which was studied, lies in the Clarke Range which is characterized by argillite, siltstone, sandstone, and limestone in resistant beds of considerable thickness.

Cordilleran glaciation has been a major force in modifying the landscape with glacial features such as U-shaped valleys, cirques, rock-basin lakes, hanging valleys, moraines and outwash, as well as present alpine glaciers (with the exception of Waterton) being common throughout the study area. The forces of gravity and running water have further modified the landscape so that colluvial slopes, alluvial fans, and floodplains are also common. A widespread but randomly distributed, thin (15 to 20 cm) silty (often silt loam) surficial capping, thought to be eolian deposited, often overlies other unconsolidated deposits. Further information regarding the surficial geology of the three Parks may be obtained in Stalker (1959, 1962), Drew (1975), and Reimchen and Bayrock (1975).

Climate

The Cordilleran region which includes the Mountain National Parks lies in a transition zone between the extreme maritime and continental climate types of the coast and the prairies (Koeppe, 1931; Hare and Thomas, 1974). Pacific disturbances move across the mountains becoming progressively drier, so that east of the Continental Divide they begin to take on the characteristics of the continental air (Heuser, 1954),

while cold arctic air moves into the mountains from the prairies and crosses the divide into Yoho (Janz, 1976). Thus, Banff and Waterton Lakes National Parks have been described as having basically continental type climates (Heuser, 1954; Longley, 1967; Janz, 1976) whereas Yoho National Park, west of the Continental Divide has been described as having basically a marine climate (Heuser, 1954). The differences in macroclimate are, however, not great among the three Parks. Winters are usually long and cold while summers are relatively short and cool (Longley, 1967), but there is a relatively high variability in seasonal and annual precipitation and temperature patterns (Janz, 1976).

Topography has an important effect on the meso-climates within this area. The northwest-southeast orientation of the mountains is almost at right angles to the prevailing winds aloft giving rise to a rainshadow effect in the valleys (Janz, 1976). In the Banff-Yoho study area, the lower portions of the Bow and Kicking Horse valleys have annual precipitations of less than 500 mm (20 in) with summer maxima, but at higher elevations (above 1,675 meters -- 5,500 feet) winter precipitation far exceeds that of summer and the annual precipitation may exceed 1,250 mm (50 in) (Janz, 1976; Janz, personal communication[1]). Topography also influences the summer temperatures in the area with cooler temperatures at higher elevations. Thus, while temperatures may reach 37 to 43^{o}C (90 to 100^{o}F) in summer, the Mount Eisenhower - Lake Louise area has about 25 days with frost during the months of June, July, and August. Average winter temperatures are usually below freezing (Janz, 1976).

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[1] Presently unpublished average annual precipitation maps.

The high winter precipitation in the form of snow, and the relatively cool high elevation summer temperatures serve to reduce the snow-free period at high elevations. Waterton has a surprisingly high average annual precipitation with 1,060 mm (43 inches) at the Park headquarters at an elevation of 1,280 meters (4,200 feet) (Environment Canada, 1971). This high precipitation is, however, offset by the high evapotranspiration in the area so that the effective climate is drier (Stringer, 1969). As with Yoho and Banff, precipitation increases with elevation (Reinelt, 1968) and summer precipitation reaches a maximum in June (Stringer, 1969).

Vegetation

The vegetation of the Rocky Mountains has been discussed and described in pieces and at various levels of detail by a number of authors since the early 1900's (Kuchar, 1973). However, inventories of the vegetation in Waterton, Yoho, and Banff National Parks have now been, or are being carried out (Kuchar, 1973, 1976; Walker *et al.*, 1975, 1976), and it is on these that the following discussion is based.

Yoho National Park has a vegetative cover of about 60 percent with the remainder being bare rock or glacier covered. Lodgepole pine and spruce forests are the most widespread and significant major vegetation types. Douglas-fir, whitebark pine, alpine fir, and alpine larch forests are less common and forests with western red cedar are decidedly rare. Herb meadows and scrub are the only important non-forest vegetation types, and are developed mainly in wetland areas, on snow-avalanche slopes, and in timberline and alpine sites. Vegetation zones range from montane to alpine. The moister climate west of the Continental Divide is reflected by the vegetation (Kuchar, 1976).

The portion of Banff National Park which lies within the study area occurs within the sub-alpine and alpine vegetative zones. The sub-alpine, which includes most of the Banff study area, has been divided into lower and upper sub-alpine subzones. The lower subzone is characterized by Engelmann spruce-subalpine fir forests on undisturbed sites and lodgepole pine forests where disturbances such as fires have occurred. The upper subzone represents a more severe climate and as such more open alpine larch or alpine fir forests are common. "Krummholz" treeforms are common within this subzone as is the occurrence of heathers in the open spaces. The alpine vegetation zone is characterized by the absence of trees. The major vegetation types present are alpine heather and _Dryas octopetala_ (Walker _et al._, 1976).

Waterton Lakes National Park has about 80 percent vegetative cover with bare rock taking up more than half of the remainder. Coniferous forest covers 35 percent of the Park and represents the single most important kind of vegetation. Lodgepole pine and alpine fir are the most abundant with Douglas fir and white spruce being present at lower elevations and Engelmann spruce, whitebark pine and alpine larch being restricted to upper elevations. Scrub vegetation resulting from wind, fire, and snow movement is well represented in Waterton with about 12 percent coverage. Scrub vegetation is made up of evergreen and deciduous shrubs to 5 meters in height and occupies a wide range of climatic and edaphic conditions. Poplar and mixed forest are important in the eastern half of the Park and in valley bottoms in the western half. Prairie grassland is also a very important, as well as distinctive, habitat type in Waterton, but the main body of it is located outside the mountain area, except for lower south-facing slopes of some of the

mountains. The vegetation in Waterton Lakes National Park includes prairie, montane, subalpine, and alpine areas, but altitudinal zonation is poorly exemplified there (Kuchar, 1973).

Soils

The soils of Waterton Lakes, Yoho, and Banff National Parks have been or are being inventoried at several levels of detail (Coen and Holland, 1976; Coen, Epp, and Tajek, in preparation; Holland et al., 1975; Walker et al., 1975; Walker et al., 1976). Soils of the Brunisolic and Podzolic orders are the most common in the study area with Luvisolic, Regosolic, Gleysolic, and Organic soils (and Chernozemic soils in Waterton) occupying lesser amounts of the landscape.

Brunisolic soils are widespread at lower elevations (below 1,675 meters -- 5,500 feet) in Yoho and Banff, with Podzolic soils becoming dominant at higher elevations, although Brunisolic and Podzolic soils occur in association throughout the area. In Waterton, the western half of the Park (which is of principal interest to this study) is dominated by Podzolic soils with Brunisolic soils occurring in the transition zones to the east. Luvisolic soils are found under dry forested conditions, and so occur on lower south facing slopes in the Bow valley in Banff and in some of the eastern parts of Waterton. Chernozemic soils are associated with the prairie grassland in Waterton. Regosolic soils are found throughout the study area on landforms that are experiencing some degree of instability, erosional modification, or geomorphic activity. Gleysolic and Organic soils are associated with wet areas such as floodplains or seepage areas and are most common at or near valley bottoms. Alpine and timberline environments have rather

unique organo-mineral (Ah) surface horizons reflecting the vegetation and climate. These soils are generally mapped in the Brunisolic and Podzolic soil orders.

METHODS

There is a basic assumption in the guidelines for assessing soil suitability for trails as used by Montgomery and Edminster and others (Table 1 and Appendix A), that each item affecting use can produce a limitation in itself, regardless of the other items affecting use. For example, if a soil is poorly drained, that soil will have a severe limitation for trail use even though all other items are rated as producing no limitation. This assumption is very important because it allows an individual evaluation of each item affecting use. If all except one of the items affecting use are kept at a level where it is generally agreed that the soil has none or slight limitations, then by looking at trails where only that item varies, varying responses (see Appendix E) should be produced which will allow an evaluation of the effects of that item. For example, to evaluate the effects of different textures, trail response can be examined on soils which are well drained with no flooding, slopes less than 15 percent[1], no stoniness[2] or rockiness problem, less than 20 percent coarse fragments, and which occur below 1,970 meters (6,500 feet) A.S.L. Any differences in trail response

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[1] Due to the scarcity of trails on sites with site slopes less than 15 percent, site slope is allowed to vary while tread slope is kept under 15 percent. No difference in trail response, other than increased difficulty of construction due to increased slope,was noted as site slope increased and tread slope was kept constant.

[2] Observations should be made on sites where the stones are greater than 7.5 meters (25 feet) apart in order to achieve complete agreement that stoniness is not a limitation at that site. This proved to be impractical, so observations where the stones are closer together are used in the comparisons, as long as stoniness is not a problem at the exact point on the trail where the observation is made.

should then be attributable to differences in texture among the sites, so the effects of differing textures can be evaluated. The details of the semi-quantitative rating scheme are provided in Appendix E.

This approach has been used in this study to evaluate the present criteria with emphasis on those in which there is disagreement among authors as to the interpretation of the criteria. When evaluating the criteria, it is assumed that: the trails will be built less than 120 cm wide, that trail grades will generally not exceed 12 percent except for short distances, and that an attempt will be made to achieve a dry, stable trail tread which is free of obstacles.

The above procedure works well with items which produce a measurable trail response, but the effects of flooding during season of use, and to lesser extent elevation, rockiness, and slope are influenced by management objectives, and so input from parks personnel is also used in the evaluation of these items.

Field Methods

The first step in evaluating the criteria was to find soils which had the necessary soil and site characteristics for the desired comparisons and which had trails on them which could be evaluated. This was accomplished through the use of soil maps which allowed for the selection of appropriate map units.

Locations for field observations were then determined by designating a starting point on the trail (eg. trail head, trail junction, or stream crossing) and pacing off a distance of 100 paces. If this distance was sufficient to get to an area where the soil and site characteristics were suitable for use in the item evaluation, then

a detailed observation was made at that site. Observations were not made in areas where the soil and site characteristics did not fall within the requirements for the desired comparisons. For example, the effects of stoniness were evaluated on sites with sandy loam, fine sandy loam or loam textures while the trail responses due to differing textures were compared on sites with low stoniness. Thus, when a site with a silt loam texture and a high amount of stoniness was encountered, the observation was not recorded since that site could not be used for the comparisons in question. In these cases, further distances of 100 paces were proceeded along the trail until the soil and site characteristics fit within the limits for the desired comparisons. Observations were then made 100 paces apart until the soil and site characteristics again became unsuitable.

Four hundred and twenty-one detailed site observations were recorded during the course of the study. The locations of the sites are shown in Fig. 2 and a summary of the observations is presented in Appendix B. The original field sheets are left on file with the Department of Soil Science at the University of Alberta.

At each site, observations of trail response (see Appendix E) were made on a 1 meter section of trail, observations of the soil were made in a soil pit dug as close as was practical to the trail section, and observations of site characteristics were made in the surrounding area (about 100 square meters), and all observations were recorded on a field sheet (Table 2). These observations were measured or estimated as follows:

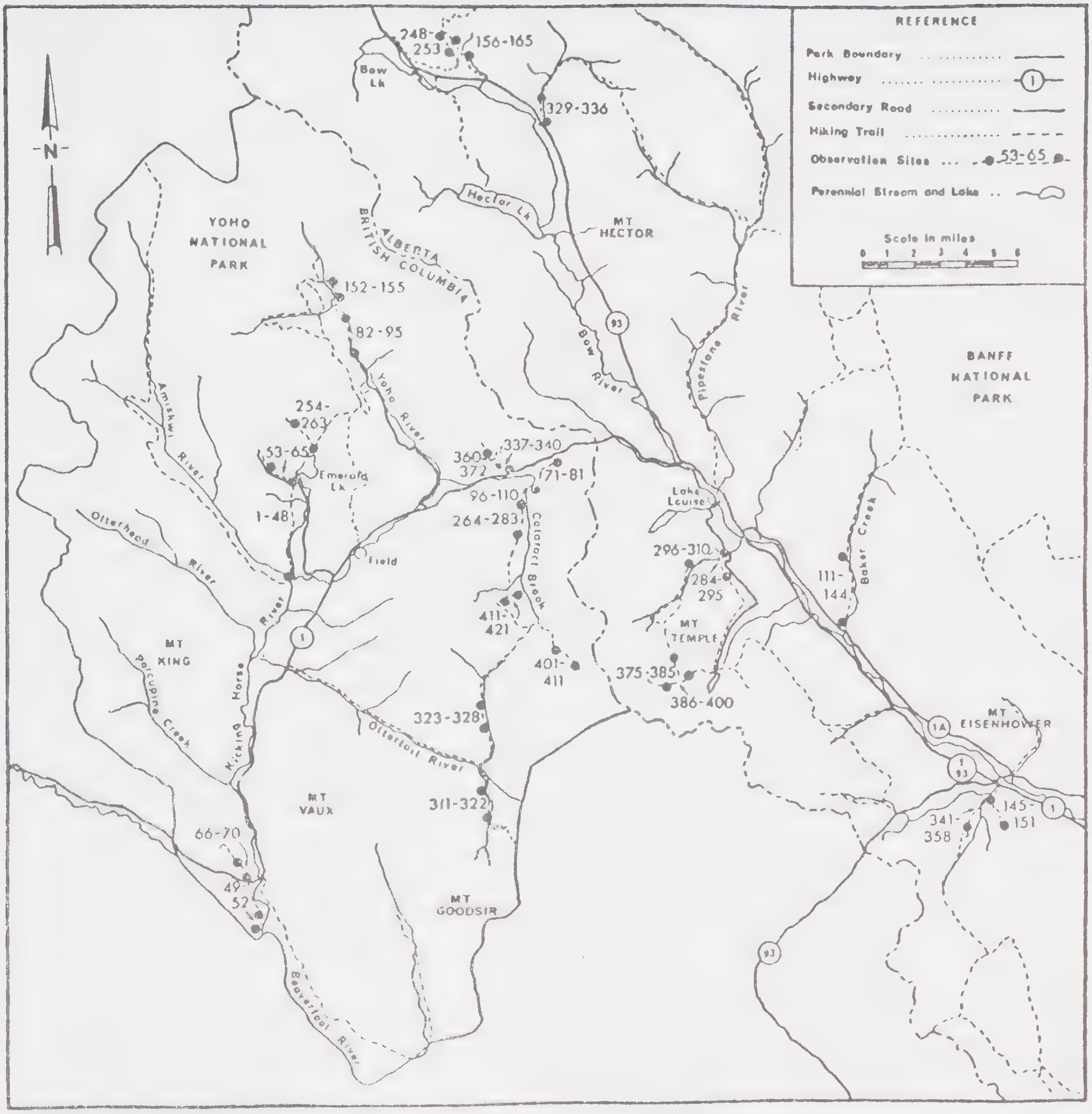

Figure 2a. Location of Observation Sites in Yoho and Banff National Parks.

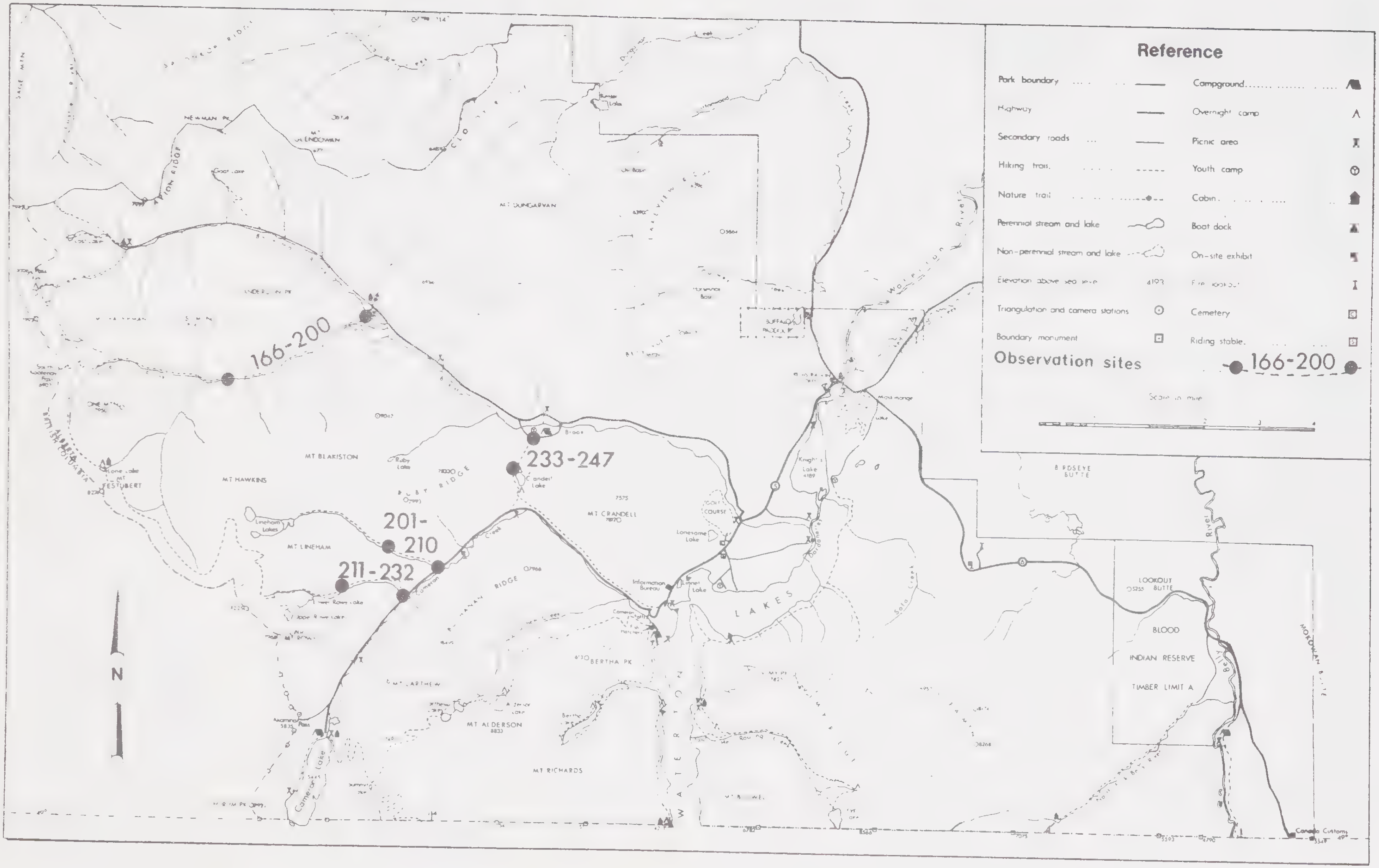

Figure 2b. Location of Observation Sites in Waterton Lakes National Park

Table 2. Field Sheet Used for Recording Site, Soil, and Trail Information at Each Observation Site

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Date ______________ Location ______________________________

Site # ____________ Map Unit ___________ Typical ____ or ________

Site

Slope ____________ Stoniness ___________ Rockiness ____________

Flooding __________ Seepage _____________ Avalanching __________

Landform __________ Elevation ___________ Vegetative Zone ______

Key Species ____

Aspect ____________ Position on Slope ___________________________

Length of Slope ____

Soil

Classification ___________________ Drainage ____________________

Water Table _____________________

Horizon	Depth	Texture	Gravel	Cobbles	Stones

Trail

Width _____________ Depth _______________ Area _________________

Muddiness _________ Dustiness ___________ Loose c.f. ___________

Embedded c.f. _____ Roots _______________

Construction ____

Maintenance ____

Design ____

Tread Slope _______ Tread Texture _______ Condition ____________

Special Notes

____

____

____

____

____

Site Parameters

Site slope was measured using a hand-held Suunto clinometer accurate to ± 1 percent. Slope values represent the slope at the site, taken by averaging slope values upslope and downslope from the site.

Stoniness and rockiness were estimated visually and classed into classes defined by CSSC (1976).

Frequency of flooding was inferred from the position on the landscape position and soil characteristics.

Amount of seepage present was inferred from vegetation and soil characteristics.

Snow avalanching was recorded as present or absent based on presence or absence of avalanche tracks.

Landforms were classified on the basis of genetic materials and surface expression according to the landform classification in the Canadian System of Soil Classification (CSSC, 1976) (see Appendix C). Field observations and aerial photographs were used to classify the landforms.

Elevation was measured with an air pressure altimeter which was adjusted daily at benchmarks in the area.

Vegetative zone was inferred from the elevation and vegetation present.

Key vegetative species were a listing of the most common trees and shrubs present.

Aspect was measured with a compass and was recorded to the nearest 45°.

Position on slope was inferred visually and through the use of aerial photographs.

Length of slope was estimated visually and through the use of aerial photographs. Slopes longer than 200 meters were designated as long or very long.

Soil Parameters

Soil classification and drainage classes were according to CSSC (1976).

Depth to water table was measured with a retractable measuring tape.

Horizon designations were made according to CSSC (1976).

Horizon depth was measured using a retractable measuring tape.

Textures were estimated by hand texturing and grouped into classes as defined by CSSC (1976), (Appendix D).

Gravel, cobble, and stone contents were estimated as a percent by volume for each horizon.

Parent material was also recorded for each soil.

Trail Parameters

Width and average depth were measured using a retractable measuring tape and were combined to give an approximate area value.

Muddiness and dustiness were rated on a scale of 1 to 5 (see Appendix E for definitions).

Loose coarse fragments were based on a visual estimate of the percentage of loose coarse fragments greater than about 1 cm in diameter on trail surface.

Embedded coarse fragments were a visual estimate of the percentage of coarse fragments greater than 2 cm in diameter which were embedded in the trail surface.

Roots were rated on a scale of 1 to 5 (see Appendix E for definitions).

Construction was recorded as a description of the special construction which was involved in building the trail.

Maintenance was recorded as a description of the maintenance which needed to be carried out on the trail.

Design was recorded as a description of how the trail was designed.

Trail tread slope was measured upslope from the site using a hand-held Suunto clinometer.

Tread texture was determined by hand texturing a sample of the trail tread and was grouped into classes as defined by CSSC (1976).

Trail condition (response) represents an overall rating of the physical condition and walkability of the trail based on the width, depth, cross-sectional area lost, muddiness, dustiness, loose and embedded coarse fragments and roots. The ratings used are 1 (good), 2 (medium), 3 (poor), 4 (very poor), and 5 (unuseable). See Appendix E for definitions of ratings and the methods of establishing the overall rating class.

Special Notes

This section consisted of observations of any other relevant information which was not included above.

In addition to the above observations, nine soil samples were taken at selected sites to verify the accuracy of the hand texturing, and to examine the influence that the fine gravel fraction has on the precision of hand texturing estimates.

Park wardens, maintenance crews, and construction crews were also interviewed in Yoho and Waterton Lakes National Parks to gain information about maintenance and construction procedures and to provide input into the more subjective parts of the interpretations.

Laboratory Methods

Particle-size analyses were carried out on the nine soil samples according to the standard procedures as outlined by McKeague (1976). The samples were first air-dried and then sieved to separate them into greater than 2 mm and less than 2 mm fractions. The greater than 2 mm fractions were then further sieved to determine the percentages of the gravel fractions present. The less than 2 mm fractions were pre-treated with hydrogen peroxide to remove organic matter and then particle-size distributions were determined by the hydrometer method. Differentiation of the sand fractions was further accomplished by means of sieving. The results of the particle-size analysis are given in Appendix G.

Data Analyses

Four hundred and twenty-one detailed observations (see Appendix B) were made during the course of this study. During the data analyses, these observations were stratified so that all parameters except one were kept constant for each different criteria evaluation. To facilitate the stratification of the observations which apply to the various evaluations, much of the data for each site were coded and punched onto Keysort cards. Then, using a sorting rod, the cards could

be sorted so that cards representing sites with the desired soil and site characteristics could be removed from the main body of cards. The sites corresponding to these cards were then checked and used for the desired evaluations.

An "average" trail response was then calculated for each group of sites in the comparisons. This was accomplished by adding all of the overall responses for the individual sites in that group and then dividing by the number of responses added. For example, in the evaluation of trail responses due to texture, 20 observations with a response of 1, 20 observations with a response of 2, and 3 observations with a response of 3 were noted for silt loam textures. Thus, the "average" trail response for that group of sites was (20 x 1) + (20 x 2) + (3 x 3) = 69 divided by (20 + 20 + 3) = 43 equals 1.60. "Average" trail responses which are calculated in the above manner are the numbers which are used in the criteria evaluations. These evaluations were made by using value judgments and statistically by using Analysis of Variance and Duncan's New Multiple Range Test as described below.

<u>Value Judgment</u>

Value judgments were made by visually comparing the "average" trail responses for the criteria in question and then deciding what degree of limitation was imposed by those soil or site characteristics. An "average" response close to 1 (good) would indicate none or slight limitations; an "average" response close to 2 (medium) would indicate moderate limitations; an "average" response close to 3 (poor) would indicate severe limitations; and an "average" response of 4 (very poor) would indicate very severe limitations due to the soil and site

characteristics for which the "average" trail response was calculated. "Average" trail responses of 5 (unsuitable) were not encountered in this study.

Duncan's New Multiple Range Test

Duncan's New Multiple Range Test was also applied to the "average" trail responses to determine whether differing responses were significantly different statistically. Due to the unequal sample sizes (numbers of observations) involved in this study, a modified procedure, as proposed by Kramer (Steel and Torrie, 1960, p. 114) was used. This involved obtaining the significant standardized ranges for Duncan's New Multiple Range Test and multiplying these by the square root of the error mean square rather than the error mean square to give a set of intermediate significant ranges (ISR). For any desired comparison, the appropriate intermediate value is then multiplied by $\sqrt{\frac{1}{2}\left(\frac{1}{r_i}+\frac{1}{r_j}\right)}$ (where r_i and r_j are the numbers of observations in the means for the desired comparison) to give the shortest significant range (SSR). This SSR is then compared to the difference being tested and the difference is then declared significant or not significant.

RESULTS AND DISCUSSION

A number of soil and site characteristics have been used, or suggested for use, as items affecting soil suitability for trail use. These include: surface texture, coarse fragments on surface, surface stoniness, wetness, rockiness, elevation, slope, flooding, landforms, parent materials, aspect, position on slope, snow avalanching, bulk density, vegetative habitat, and carbonate content. These items are individually evaluated and discussed below. For each item, the present interpretations of that item are first presented (Table 1 and Appendix A). This is followed by the results of this study pertaining to that item and then a discussion of the limitations for trail use imposed by that item. The individual items affecting use are then combined to form the Guidelines Table which is presented in the following section.

An example of the complete statistical analysis used is given below under Soil Suitability as Affected by Surface Texture. For the remainder of the items evaluated, details of the statistical analysis are given in Appendix F. The statistical procedures used throughout are the same as that used for the evaluation of surface texture.

Soil Suitability for Trails as Affected by Surface Texture

There is general agreement among the guidelines (Table 1 and Appendix A) as to the suitability for trail use of the various textures, with one very important and several minor differences. It is agreed that sandy loam (SL), fine sandy loam (FSL), very fine sandy loam (VFSL), and

loam (L) textures represent none or slight limitations, that clay loam (CL), sandy clay loam (SCL), silty clay loam (SiCL), and loamy sand (LS) textures represent moderate limitations, and that sand (S) and organic (O) textures represent severe limitations. There is disagreement as to whether a silt loam (SiL) texture represents a slight or a moderate limitation and as to whether clay (C), sandy clay (SC), and silty clay (SiC) textures represent moderate or severe limitations to trail use. The differences in the interpretation of silt loam textures is very important in the mountain National Parks due to the widespread silty (silt loam) surficial deposits which cover a good deal of the area, while the other three differences are of minor importance to this study due to the scarcity of these textures in the mountain National Parks.

To evaluate the textural criteria, observations of trail response (Appendix E) on sandy loam, fine sandy loam, loam, silt loam, silty clay loam, and clay loam textures were compared on well drained sites with no flooding or seepage, stoniness classes 0 to 2 (stones greater than 2 meters apart), rockiness class 0 (no rockiness), less than 20 percent coarse fragments, elevations less than 1,820 meters (6,000 feet) ASL, and trail tread slopes less than 15 percent.

The sites which were used for this comparison are as follows:

SL 72, 73, 105, 190[1], 276, 278, 281, 284, 297, 305.

FSL 2, 27, 29, 30, 46, 47, 74, 99, 102, 264, 280, 282, 287, 294, 295.

L 5, 42, 45, 100, 101, 104, 199, 237, 275, 303, 308, 351, 364, 367.

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[1] Indicates occasional flooding but response indicates no adverse effects influencing the use of this site for evaluating textures.

SiL 7, 8, 12, 13, 17, 34, 40, 59, 62, 94, 108, 112, 115, 118, 122, 123, 124, 129, 131, 135, 140, 141, 175, 196, 197, 198, 225, 236, 243, 245, 259, 260, 261, 262, 263, 291, 296, 338, 339, 340, 344, 360.

SiCL 3, 6, 9, 69, 239.

CL 103, 130, 134, 341.

The results of these observations are summarized in Table 3.

Table 3. Textural Results

Texture		SL	FSL	L	SiL	SiCl	CL	Combination
	1	11	12	10	20	4	2	
Observations	2	-	3	4	20	1	2	
(Responses)	3	-	-	-	3	-	-	
	4	-	-	-	-	-	-	
	5	-	-	-	-	-	-	
Sample total, T		11	18	18	69	6	6	128 = Grand Total G
Sample size, n		11	15	14	43	5	4	92 = Σn
Sample mean, $\bar{y}$		1.00	1.20	1.29	1.60	1.20	1.50	1.39 = $\bar{\bar{y}}$
$\frac{T^2}{n}$		11.0	21.6	23.1	110.7	7.2	9.0	182.6 = $\sum(\frac{T^2}{n})$

The numbers listed in the top 5 rows of Table 3 indicate the number of individual observations of each response for each texture. For example, with the stated soil and site characteristics and a silt loam texture, a response of 1 was observed 20 times, a response of 2 was observed 20 times, and a response of 3 was observed 3 times. The sample total (T) represents the sum of the individual observations for each

texture. For example, the sample total of 69 for silt loam is arrived at by adding (20 x 1) + (20 x 2) + (3 x 3). The sample size (n) represents the number of individual responses contributing to each sample total, eg. 20 + 20 + 3 = 43 for the silt loam texture. The sample total is then divided by the sample size to give the sample mean $\bar{y}$, eg. 69 divided by 43 = 1.60 for silt loam. The grand total (G) which is the sum of the sample totals, the sum of n (Σn) which is the sum of the sample sizes, the general mean ($\bar{\bar{y}}$) which is the mean of all the observations, and the statistics $\frac{T^2}{n}$ and $\Sigma \frac{T^2}{n}$ are also calculated for use in the analysis of variance (Table 4).

Table 4. Analysis of Variance for Textural Results

Preliminary Calculations

(1) Type of Total	(2) Total of Squares	(3) No.of Items Squared	(4) No.of Observations Per Squared Item	(5) Total of Squares Per Observation (2) - (4)
Grand	16,384 (G^2)	1	92 (Σn)	178.1 = $G^2/\Sigma n$ (I)
Sample	-	-	-	182.6 = $(T^2/n$(II)
Observation	-	-	-	206 = y^2 (III)

Analysis of Variance

Source of Variation	Sum of Squares		Degree of Freedom		Mean Square	F
Among sample	4.5	II-I	5	k - 1	0.9	3.33
Within Sample	23.4	III-II	86	n - k	0.27	
Total	27.9	III-I	91	n - 1		

The critical region for 5 and 86 degrees of freedom at the 5 percent confidence level is where F is greater than 2.324. Therefore, the calculated F is inside the critical region and the hypothesis that the means of the responses of the various textures are equal is rejected.

Since the means are shown to be significantly different at the 5 percent confidence level, Duncan's New Multiple Range Test is applied to the means. The means of the responses for the six textural classes are arranged according to their magnitudes as follows:

Textural Class	SL	FSL	SiCL	L	CL	SiL
Mean Response	1.00	1.20	1.20	1.29	1.50	1.60

Due to the unequal sample sizes, a procedure proposed by Kramer (Steel and Torrie, 1960, p. 114) is used when applying Duncan's New Multiple Range Test (Table 5). The Significant Studentized Ranges are obtained

Table 5. Duncan's New Multiple Range Test Assessing the Influence of Texture on Trail Response

g	Textures	Difference	Sig Stud. Range	ISR	SSR	Conclusion
6	SiL-SL	0.60	3.19	1.66	0.40	Significant
5	SiL-FSL	0.40	3.13	1.63	0.35	Significant
4	SiL-SiCL	0.40	3.06	1.59	0.53	Not Significant
3	SiL-L	0.31	2.96	1.54		Not Significant
2	SiL-CL	0.10	2.81	1.46		Not Significant
5	CL-SL	0.50	3.13	1.63	0.67	Not Significant
4	CL-FSL	0.30	3.06	1.59		Not Significant
3	CL-SiCL	0.30	2.96	1.54		Not Significant
2	CL-L	0.11	2.81	1.46		Not Significant
4	L-SL	0.29	3.06	1.59	0.45	Not Significant
3	L-FSL	0.09	2.96	1.54		Not Significant
2	L-SiCL	0.09	2.81	1.46		Not Significant
3	SiCL-SL	0.20	2.96	1.54	0.59	Not Significant
2	SiCL-FSL	--	--	--		Not Significant
2	FSL-SL	0.20	2.81	1.46	0.41	Not Significant

from the Range table and are then multiplied by the s (s is the square root of the error mean square calculated in the analysis of variance) to give intermediate studentized ranges (ISR). The intermediate studentized ranges are then multiplied by $\sqrt{\frac{1}{2}\left(\frac{1}{r_i}+\frac{1}{r_j}\right)}$ (where r_i and r_j are the number of observations in the means for the desired comparison) to give the shortest significant ranges (SSR) which are compared to the differences to determine which differences are significant. The results of the new multiple range test are summarized in Table 6.

Table 6. Results of Duncan's New Multiple Range Test Assessing the Influence of Texture on Trail Response

Texture	SL	FSL	SiCL	L	CL	SiL
Mean Responses	1.0	1.20	1.20	1.29	1.50	1.60

Any two means which are not underscored by the same line are considered to be significantly different at the 5 percent significance level. In this case, sandy loam and fine sandy loam are not underscored by the same line as is silt loam, so the response of trails on sandy loam and fine sandy loam textured soils may be considered to be significantly better than the trail response on silt loam textured soils.

Discussion

The comparison of means indicates that trail response does vary with the texture upon which the trail is constructed. Trails on

sandy loam textures show consistently good responses while trails on clay loam and silt loam textures show medium responses more often than or as often as good responses.

Having established that soil texture (as grouped into textural classes) does cause significantly different trail responses, it is then necessary to divide the continuum into several limitation classes. Trail responses on sandy loam, fine sandy loam, and loam textures are relatively good and so these textural classes are left as causing slight limitations for trail use. Silt loam textures are shown to have a significantly poorer trail response than sandy loam textures and so the silt loam textural class is rated as having moderate limitations for trail use. Clay loam and silty clay loam textures do not show significantly different responses from sandy loam textures, but present a definite trend which probably would prove to be significant with a larger sample size. This trend, along with field observations, indicates that clay loam and silty clay loam textural classes should be rated as having moderate limitations for trail use. Clay, silty clay and sandy clay textures are left as severe limitations (in agreement with majority of previous guidelines) due to lack of evidence from this study to the contrary. The refined guidelines for texture are shown in Table 7.

Table 7. Guidelines for Assessing Soil Limitations for Trails Resulting from Texture

	Degree of Limitation		
	None to Slight	Moderate	Severe
Texture	SL, FSL, VFSL, L	SiL, SiCL, CL, SCL, LS	S, Organic, SC, SiC, C

The types of trail deterioration associated with texture were muddiness, dustiness, wear, and/or erosion. Muddiness and wear were most common on gentle slopes while erosion became more prevalent as the tread slopes approached 15 percent, especially when the trail ran straight upslope. Dustiness occurred rather infrequently under dry conditions. Muddiness and wear problems can be overcome by raising the trail tread and by adding coarser material to the tread. Erosion can be overcome by designing the trail so that water does not run down the trail for a significant distance.

It should be noted that the results for texture show a gradation from good to medium and that the break between slight and moderate limitations are rather arbitrary. Thus, while textures rated as having slight limitations show a generally good response, small problems will occur. Similarly, textures which result in moderate limitations generally show medium responses, but portions of trails with these textures do show good responses, especially when well designed.

It is also suggested that the term surface texture (Table 1 and Appendix A) is irrelevant in the mountains due to the steep slopes which often result in trails being built in a horizon other than the surface horizon. Thus, it is suggested that this item be termed textural class, which is defined as the textural class (CSSC, 1976) which will be dominant at the depth which is reached by the trail construction.

Soil Limitations for Trails as Affected by Coarse Fragments on Surface and Surface Stoniness

Coarse fragments on surface and surface stoniness have been treated as two separate items in the guidelines (Table 1 and Appendix A), but they are discussed together here for the sake of convenience, since they are arbitrary breaks on a continuum. Coarse fragments on surface, as used in the guidelines, refers to the percentage of gravel[1] and cobble[1] sized coarse fragments while stoniness refers to the stone[1] sized coarse fragments (Coen and Holland, 1976).

Less than 20 percent coarse fragments are usually considered to present none to slight limitations for trail use, 20 to 50 percent coarse fragments are considered to present moderate limitations, and greater than 50 percent coarse fragments are considered to present severe limitations (Table 1 and Appendix A). However, Vold (1975) suggested that 10 to 50 percent coarse fragments presented none to slight limitations, 50 to 75 percent coarse fragments presented moderate limitations, and greater than 75 percent coarse fragments presented severe limitations for trail use. These changes were made by Vold because it was felt that medium contents of coarse fragments resulted in the most durable sites.

Stoniness has been described both in terms of mean distance between stones and in terms of stoniness classes (Table 1 and Appendix A). Strict comparisons between the distances and the stoniness classes are impossible because until recently (CSSC, 1974), stoniness classes

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[1] By definition (CSSC, 1976) gravel ranges from 2 mm to 8 cm in diameter, cobbles range from 8 to 25 cm in diameter, and stones are greater than 25 cm in diameter.

were only defined in terms of the difficulty that the stones presented to cultivation. However, applying the present (CSSC, 1976) distance between stones criteria to the stoniness classes given in the limitations for trail guidelines (Table 1 and Appendix A) indicates the differences in interpretation shown in Table 8.

Table 8. Examples of Differences in the Interpretation of the Influence of Stoniness on Soil Limitations for Trails

	Degree of Limitation		
	None to Slight	Moderate	Severe
Coen and Holland (1976)	Stones >7.5 m apart (S0, S1)	Stones 1.5 - 7.5 m apart (S2)	Stones <1.5 m apart (S3 - S5)
Greenlee (1976)	Stones >2 m apart (S0 - S2)	Stones 1 - 2 m apart (S3)	Stones <1 m apart (S4, S5)

For the purposes of this study, gravels and cobbles have been evaluated separately. This was done because of the tremendous size difference between the smallest gravel (2 mm) and the largest cobbles (25 cm). However, because of the limited range of data available from this study for varying cobble contents, results for cobble contents and stoniness are presented together.

To evaluate the effects of varying gravel contents, observations were compared on well and moderately well drained sites (some with occasional flooding) with sandy loam tread textures, tread slopes less than 15 percent, stoniness classes 0 to 2, no rockiness, cobble contents less than 10 percent, and elevations below 1,820 meters (6,000 ft) ASL.

A listing of the sites compared and details of the statistical analysis are provided in Appendix F-1.

The mean responses of the varying gravel contents with the above soil and site characteristics are given in Table 9. The hypotheses that the means are equal was rejected at the 5 percent confidence level, so Duncan's New Multiple Range Test was carried out with the results shown in Table 8.

Table 9. Results[1] of Duncan's New Multiple Range Test Assessing the Influence of Gravel Contents on Trail Response

Gravel Content	0 - 20%	20 - 50%	>50%
Mean Responses	1.0	1.1	1.63

[1] Any two means not underlined by the same line are considered to be significantly different at the 5% confidence level.

To evaluate the effects of varying stoniness[1] and cobble contents, observations were compared on well drained sites with no flooding or seepage, no rockiness, tread slopes less than 15 percent, sandy loam, fine sandy loam or loam tread textures, and less than 50 percent gravel contents. A listing of the sites compared and details of the statistical analysis are provided in Appendix F-2.

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[1] For the purposes of this study, stoniness classes are defined as:
S0 - stones more than 30 m apart and cover less than 0.01% of surface.
S1 - stones 10-30 m apart and cover 0.01-0.1% of surface.
S2 - stones 2-10 m apart and cover 0.1-3% of surface.
S3 - stones 1-2 m apart and cover 3-15% of surface.
S4 - stones 0.1-0.5 m apart and cover 15-50% of surface.
S5 - stones less than 0.1 m apart and cover greater than 50% of surface.
Stones refers only to coarse fragments greater than 25 cm in diameter.

The mean responses of the varying stoniness and cobble contents are given below in Table 10. The hypotheses that the means are equal was rejected at the 5 percent confidence level so Duncan's New Multiple Range Test was carried out with the results as shown in Table 10.

Table 10. Results[1] of Duncan's New Multiple Range Test Assessing the Influence of Stoniness and Cobble Contents on Trail Response

Stoniness and Cobble Content	S1 0 - 5%	S2 0 - 5%	S2 6 - 10%	S3 0 - 5%	S3 6 - 10%
Mean Responses	1.00	1.00	1.20	1.67	2.00

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

Discussion

The comparison of the means for varying gravel contents shows that trail response does vary with gravel content. Trails on sites with less than 50 percent gravel show consistently good responses, while trails on sites with greater than 50 percent gravel content show a significantly poorer response.

These results show that gravel content may be considered as a separate item affecting use with less than 50 percent gravel producing none or slight limitations and greater than 50 percent gravel producing moderate limitations as shown in Table 11.

Only a limited range of results is available for evaluating

the effects of cobble contents. However, it can be seen that a relatively good trail response is still maintained with 6 to 10 percent cobbles at a stoniness of S2 but that response is poorer in both S2 and S3 as cobble content increases. These results show that trail response does vary with cobble content and it is suggested that limits of 0 to 20 percent for none to slight limitations, 20 to 50 percent for moderate limitations, and greater than 50 percent for severe limitations be used for cobbles as shown in Table 11.

Table 11. Guidelines for Assessing Soil Limitations for Trails Resulting from Gravel Contents, Cobble Contents, and Stoniness

Item Affecting Use	Degree of Limitation		
	None to Slight	Moderate	Severe
Gravel Content	0 - 50%	>50%	Not applicable
Cobble Content	0 - 20%	20 - 50%	>50%
Stoniness	Stones >2 meters apart	Stones 1 - 2 meters apart	Stones <1 meter apart

The available results for the stoniness classes show that trail response does vary with stoniness, with a significantly poorer response being shown at a stoniness of 3. Thus, stones greater than 2 meters (6.5 ft) apart is rated as none to slight limitation while stones between 1 and 2 meters (3.3 - 6.5 ft) apart is rated as having moderate limitations. Following this trend, stones less than 1 meter (3.3 ft) apart are rated as severe limitations for trail use. These ratings are shown in Table 11.

The types of trail deterioration shown by trails with high gravel contents were primarily loose or unstable footing and increased erosion, especially as gravel contents reached 80 or 90 percent. These problems occur due to the lack of fine material binding the soil together and are more noticeable on steeper trail treads. The erosion potential is further amplified when the gravels consist of flat shales which are oriented parallel to the slope. Plate 1 shows an example of what can happen when a large volume of water is diverted down a trail with a high shaley gravel content. Moderate amounts (20 to 50 percent) of gravel do have a beneficial effect though when they occur in conjunction with medium or fine textures, because of the stabilizing influence which they have on these textures. This was especially true of the silt loam texture which showed an "average" trail response of 1.31 with 20 to 50 percent gravels as compared to an "average" trail response of 1.60 with 0 to 20 percent gravels.

Cobbles and stones increase the construction difficulties when they must be removed during construction or present obstacles to travel when they are not removed. Cobbles and stones may be exposed further by trail wear or erosion and so present more of a problem when they occur in conjunction with adverse soil textures. Some soil stabilization may also be contributed by cobbles and stones, but the disadvantages of high amounts of cobbles and stones generally outweigh the advantages.

The guidelines which are presented here are based on average sized gravels and cobbles, and on stones which are generally not much greater than 25 cm. These guidelines are also based on comparisons of observations where the other sizes of coarse fragments are low. For example, stoniness is evaluated with 0 to 5 percent cobbles. When

Plate 1. Erosion resulting from water being diverted onto a trail which was built on a soil with about 80% shaly gravels.

gravels and cobbles reach their upper size limits, trail response will be similar to the response to cobbles and stones, respectively. Similarly, as stones get larger the limitations they cause are more severe. There are also interactions among the coarse fragments, especially between cobbles and stones, such that as cobble contents approach 20 percent and stones get close to 2 meters apart, the interaction will produce a limitation even though one is not specified in the guidelines. Therefore, it is important to keep the actual sizes and numbers of the coarse fragments in mind when making the interpretations rather than sticking strictly to the limits specified in the guidelines.

As with texture, gravels and cobbles on surface are irrelevant for the purpose of predictions in the mountainous areas. Therefore, it is suggested that these items be termed gravel contents and cobble contents which are defined as being respectively, the average gravel and cobble percentages which occur within the depth of soil in which the trail is built.

Soil Limitations for Trails as Affected by Wetness

Drainage and depth to water table during season of use are generally considered together under the term wetness. The exception to this is Vold (1975) who considers only drainage. There is agreement among all the guidelines (Table 1 and Appendix A) as to the degree of limitation imposed by the various drainage classes, but there is disagreement as to the depth of the seasonal water table associated with the drainage classes. Rapidly, well, and moderately well drained soils with seasonal water tables below 50 cm (20 in) or below 90 cm (36 in) are considered

to present none to slight limitations, moderately well drained soils subject to seepage or ponding and imperfectly drained soils with seasonal water tables above 50 cm (20 in) for short periods or between 30 and 90 cm (12 to 36 in) are considered to present moderate limitations, while poorly and very poorly drained soils with seasonal water tables near the surface are considered to present severe limitations for trail use. The only real difference is the interpretation of the depth of water table associated with none to slight limitations.

To evaluate the effects of differing wetnesses, observations should be made at sites where all other soil and site characteristics are good, that is, among other things, the texture should be sandy loam. However, imperfectly, poorly, and very poorly drained soils are generally associated with floodplains or seepage areas where silt loam textures are dominant. In addition, these areas are generally considered to be less desirable trail locations, so the amount of trails on these sites is low. Thus, the comparison of wetness is made on sites with silt loam tread textures, less than 20 percent coarse fragments, stoniness of 0 to 2, no rockiness, tread slopes less than 15 percent, and elevations below 1,820 m (6,000 ft). Flooding and/or seepage are usually associated with the poorer drainages. A listing of the sites compared and details of the statistical analyses are provided in Appendix F-3. The results of the Duncan's New Multiple Range Test are shown in Table 12.

Discussion

The comparison of the means shows that trail response does vary with wetness on sites with silt loam textures. Trails on imperfectly drained sites show a significantly poorer response than trails

Table 12. Results[1] of Duncan's New Multiple Range Test Assessing the Influence of Wetness on Trail Response

Wetness	Well	Mod. Well W.T.[2] >90 cm	Mod. Well W.T.[2] 50-90 cm	Imperfect	Poor
Mean Responses	1.60	1.90	2.18	2.21	3.29

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

[2] W.T. = water table.

on well drained sites and trails on poorly drained sites show significantly poorer responses than trails on imperfectly drained sites. The responses of trails on moderately well drained sites with seasonal water tables below 90 cm are not significantly different than responses of trails on either well or imperfectly drained sites but trails on moderately well drained sites with seasonal water tables at 50 to 90 cm show a significantly poorer response than trails on well drained sites. These results suggest that moderately well drained soils with seasonal water tables above 90 cm should be interpreted the same as imperfectly drained soils.

It is suggested that the variations in trail response with changes in wetness would also occur on sandy loam textured sites, as has been shown on silt loam textured soils. Thus, the present (Table 1 and Appendix A) wetness criteria for drainage are accepted without change. The observations of trails on silt loam textured sites indicate that for silt loam textures, 90 cm rather than 50 cm should be used as

the depth criterion for seasonal water tables. However, several observations (Sites 18, 22, 311, 312, 319, 322) of trails on sites with very gravelly sandy loam or loamy sand textures at or near the surface show good responses even when the water table is above 50 cm. These results indicate that a higher water table is acceptable with coarser textures, so it is suggested that greater than 50 cm be taken as the depth to seasonal water table for none to slight limitations, while recognizing that seasonal water tables between 50 and 90 cm do cause problems with finer textures. The refined guidelines for wetness are shown in Table 13.

Table 13. Guidelines for Assessing Soil Limitations for Trails Resulting from Wetness

	Degree of Limitation		
	None to Slight	Moderate	Severe
Wetness	Rapidly, well, and moderately well drained soils. Water table below 50 cm during season of use.	Moderately well drained soils subject to seepage and ponding and imperfectly drained soils. Water table may be above 50 cm for short periods during season of use.	Poorly and very poorly drained soils. Water table above 50 cm and often near surface for a month or more during season of use.

Increased muddiness is the main problem which is associated with increased wetness. Wetness problems can be overcome with construction, but the use of a boardwalk or similar construction, results in greater construction difficulties. If no special construction is

used, sustained use of the wet sites will result in muckiness and ever-increasing trail widths as users try to avoid the muddy spots.

There appears to be an interaction between wetness and texture such that adverse wetness combined with adverse textures produces a severer limitation than the wetness or texture alone. For example, the average response due to silt loam textures was 1.60, but when trails on imperfectly drained sites with silt loam textures were evaluated, the average trail response was 2.21 which was significantly worse at the 5 percent confidence level. As with texture, moderate amounts of gravel sized coarse fragments tend to decrease wetness problems.

Soil Limitations for Trails as Affected by Rockiness

Rockiness has been described both in terms of rockiness classes and in terms of percent area covered and distance between outcroppings (Table 1 and Appendix A). The range in the present interpretations of the influence of rockiness on soil limitations for trails is given in Table 14.

An objective comparison of the effect of increasing rockiness proved to be difficult because of the limited number of trails in areas of high amounts of rock outcroppings and because of the steeper tread slopes and the coarse fragment and stoniness problems which were often associated with these trails. It is assumed, that the steeper tread slopes result from design limitations imposed by the bedrock and assuming that the coarse fragment and stoniness problems are directly related to the bedrock. This allows the comparison of observations on

Table 14. Examples of Differences in the Interpretation of the Influence of Rockiness on Soil Limitations for Trails

	Degree of Limitation		
	None to Slight	Moderate	Severe
Coen and Holland (1976)	Rock exposures cover less than 10% of the surface. (R0, R1)	Rock exposures cover 10-25% of the surface. (R2)	Rock exposures cover more than 25% of the surface. (R3-R5)
Montgomery and Edminster (1966)	Rock exposures cover less than 25% of the surface. (R0-R2)	Rock exposures cover 25-50% of the surface. (R3)	Rock exposures cover more than 50% of the surface. (R4,R5)

rapidly and well drained sites with no flooding or seepage, sandy loam or loam tread textures, and tread slopes less than 20 percent. (The observations on sites with no rockiness were further restricted to stoniness 0 to 2, less than 50 percent coarse fragments and tread slopes less than 15 percent since there was no rockiness present to relate the extended limits to.) A listing of sites used and details of the statistical analysis are given in Appendix F-4. The results of the Duncan's New Multiple Range Test are given in Table 15.

This comparison of the mean responses shows that trail response does vary with rockiness as trails on sites with greater amounts of rockiness show increasingly poorer responses. These results suggest that even slightly rocky sites (R1) have moderate limitations for trails and that exceedingly rocky (R4) and perhaps very rocky (R3) sites have severe limitations for trails. Based on these results, the suggestion is made that R2 (10 to 25 percent cover with rock outcroppings) be rated as having a moderate rather than a none to slight rating and that R3 (25 to 50 percent cover with rock outcroppings)

Table 15. Results[1] of Duncan's New Multiple Range Test Assessing the Influence of Rockiness on Trail Response

Rockiness	R0	R1	R2	R3	R4
Mean Responses	1.16	1.75	2.33	2.50	2.67

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

be rated as having a severe rather than moderate limitations for trails, as is shown in Table 16. These evaluations should be viewed with caution, however, because of the limited numbers of observations for most of the rockiness classes and the rather subjective assumptions which were made in selecting observations for comparison.

Table 16. Guidelines for Assessing Soil Limitations for Trails Resulting from Rockiness

	Degree of Limitation		
	None to Slight	Moderate	Severe
Rockiness	Rock outcrops cover less than 10% of area. (R0, R1)	Rock outcrops cover 10-25% of area. (R2)	Rock outcrops cover more than 25% of area. (R3, R4, R5)

One of the major problems associated with rockiness was the limitation of possible trail routes. It was often noted that trail

tread slopes were overly steep in rocky areas and also that trails were constructed in depressions where water was channeled down the trails leading to erosion problems. Other problems associated with trails on or near rock outcroppings were a high percentage of coarse fragments on the trail surface and more cobbles and stones in the trail tread. Most of the trails observed had been built in such a way that little or no bedrock had to be moved during construction but where this was necessary, construction difficulties increased accordingly.

It should also be noted that the degree of limitation imposed by an area of bedrock outcropping varies greatly with the nature of the outcropping. The high percentage of bedrock in Plate 2 imposes only moderate limitations for trail use since it is essentially flat lying, but the cliff shown in Plate 3 necessitated the construction of a tunnel. Thus, the limits given in Table 14 serve only as general guidelines, and site specific observations of the nature of the rockiness in terms of trail objectives are very important. Occasionally, it may be possible and desireable to build trails over rock outcroppings due to the resistance of the bedrock to environmental damage, but again site specific evaluations will be required.

Soil Limitations for Trails as Affected by Elevation

Elevation has only been used as an item affecting use by Vold (1975), but since this criterion was used in Yoho National Park, it is evaluated here. Soils at elevations above 1,970 m (6,500 ft) ASL were rated as having moderate limitations for trail use.

The criterion of elevation was evaluated by comparing

Plate 2. Trail showing medium response despite more than 50% of the area consisting of bedrock.

Plate 3. A tunnel through bedrock is used to overcome this rockiness problem on the Crypt Lake trail in Waterton Lakes National Park.

observations of trail response at elevations below 1,820 m (6,000 ft) ASL and above 2,120 m (7,000 ft) ASL on both sandy loam and silt loam textured sites which were well drained with no flooding or seepage, less than 20 percent coarse fragments[1], stoniness classes 0 to 2 (stones greater than 2 m apart), no rockiness, and tread slopes less than 15 percent. A listing of the sites compared and details of the statistical analysis are given in Appendix F-5. The results of the Duncan's New Multiple Range Test are given below in Table 17.

Table 17. Results[1] of Duncan's New Multiple Range Test Assessing the Influence of Elevation on Trail Response

Texture and Elevation	SL >2,120 m ASL	SL <1,820 m ASL	SiL <1,820 m ASL	SiL >2,120 m ASL
Mean Responses	1.00	1.06	1.60	1.71

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

This comparison of the mean responses for elevation shows that there is no significant difference in response among trails on sites below 1,820 m (6,000 ft) ASL and above 2,120 m (7,000 ft) ASL when the other items affecting use are kept constant. Thus, these results suggest that on the basis of trail deterioration alone, elevation is not suitable for use in the guidelines as an item affecting use. As such, elevation per se will not be considered in the guidelines table.

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[1] Comparisons with SL textures are made with >50 percent coarse fragments.

There are, however, a number of important considerations when planning to use high elevation sites for trails. The length of the season of use generally decreases as elevation increases due to higher snowfalls and cooler summer temperatures. Trails in alpine or near-alpine environments often remain impassable until late July and may retain snowbanks for the entire summer (Plate 4). Secondly, use of alpine areas often begins as soon as access is possible. At the time of snowmelt, the subsurface soil is still frozen, so the water from the melting snow saturates the surface soil. The trail treads then become muddy and are quickly abandoned leading to the multiple trail formation which is common to many alpine areas (Plate 5). This problem is amplified by medium and fine soil textures, and by trail locations below late melting snowbanks and at or near valley bottoms where melt water sustains wet soil conditions. Multiple trail formation is rare on coarse textured soils and on drier south facing slopes. Much of the multiple trail tread formation problem could be eliminated by choosing sites which dry sooner after snowmelt or by restricting use until after the trails are dry. A third consideration in the use of high elevation sites is the fragility of the alpine vegetation. This is not a problem when hikers stay on the trails, but can become an important management problem in high use areas where people tend to wander off the trails.

All three of the above considerations are important, but as the evidence indicates that trails in alpine environments do not respond significantly differently than trails at lower elevations under similar use conditions, these considerations are not felt to be justification to adopt elevation as a soil related criteria causing a limitation

Plate 4. Wenchemna Pass (Banff) on August 23, 1976. Numerous snowbanks still remain on this northeast facing aspect.

Plate 5. Multiple tread formation which is typical of many alpine trails. Note the wet trail conditions resulting from snowmelt.

for use of a given site for trails. Interpretations for alpine and upper sub-alpine areas should be footnoted, however, to draw attention to the short season of use and management problems which exist in these areas.

Soil Limitations for Trails as Affected by Slope

There is a general agreement among the guidelines (Table 1 and Appendix A) that 0 to 15 percent site slopes pose none to slight limitations, 15 to 30 percent site slopes pose moderate limitations, and greater than 30 percent site slopes pose severe limitations for trail use. The exception to this is Vold (1975), who includes 30 to 60 percent site slopes under moderate limitations and then rates only greater than 60 percent site slopes as having severe limitations for trail use.

The effects of site slope on trail response were evaluated by means of a comparison of observations of trails on well drained sites with no flooding or seepage, tread slopes 0 to 15 percent, sandy loam textures, 0 to 50 percent coarse fragment contents, stoniness 0 to 2, no rockiness, and elevations less than 1,820 m (6,000 ft). The groups of site slopes compared consisted of 0 to 15 percent, 16 to 30 percent, and 31 to 60 percent. A listing of the sites used and details of the statistical analysis are given in Appendix F-6. The results of the analysis of variance are given below in Table 18. The mean responses are not significantly different at the 5 percent confidence level, even though the observations compared had site slopes ranging from 2 to 55 percent, so Duncan's New Multiple Range Test is not carried out.

Table 18. Results[1] of the Analysis of Variance Assessing the Influence of Site Slope on Trail Response

Site Slope	0 - 15%	16 - 30%	31 - 60%
Mean Responses	1.00	1.00	1.11

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

Discussion

The above results show that trail response does not vary significantly with site slope, as long as trail tread slopes are kept constant. Increased site slopes do, however, increase construction difficulties as is illustrated in Figure 3. This diagram illustrates the relative amounts of material which must be removed to obtain level trail treads with varying slopes. It is intuitively obvious that there is a considerable increase in the amount of excavation required to obtain a level tread as site slope varies from 15 to 60 percent, especially when a vertical cut slope is not practical. This suggests that there is a need for a break at 30 percent and that a footnote indicating extra severe limitations should be used on slopes greater than 60 percent. These refined guidelines are shown in Table 19.

Table 19. Guidelines for Assessing Limitation for Trails Resulting from Site Slope

	Degree of Limitation		
	None to Slight	Moderate	Severe
Slope	0 - 15%	15 - 30%	>30%

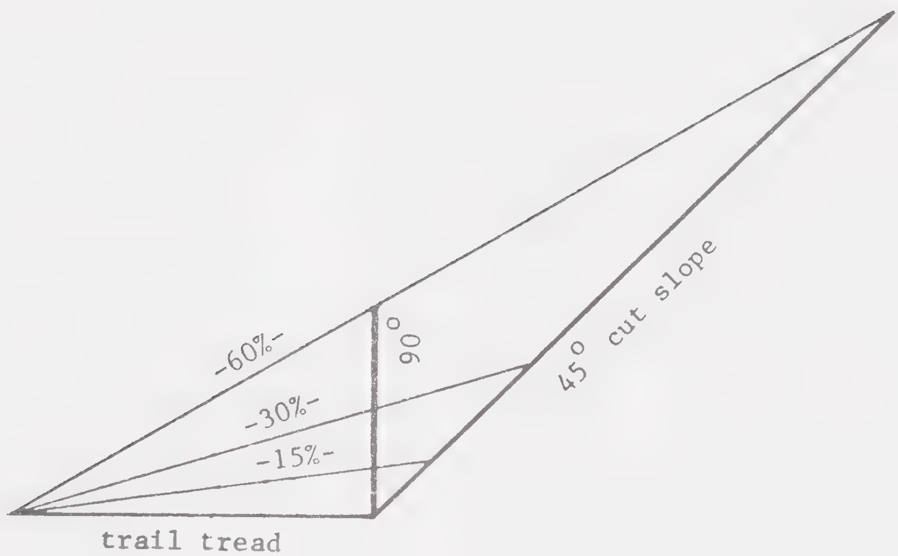

Figure 3. Relative amounts of excavation required to obtain level trail treads on 15, 30, and 60 percent slopes, with 90° and 45° cut slopes are indicated by the area within the appropriate triangles.

As shown by the results, the major effect of site slope is on construction costs which increase with site slope. There are, however, several interactions between site slope and other items affecting use. Trails on soils which are rated as having moderate limitations due to texture often show tread wear. On level and gently sloping areas, this results in a depressed trail tread which accumulates water

and leads to muddy conditions. On slightly steeper site slopes (10 to 20 percent) there is a tendency to orient the trail straight upslope when this is the shortest route to the desired objective. When trails are oriented perpendicular to the contour, water can not easily be shunted off the trail. This allows the water to gain destructive energy which may cause erosion problems. However, on steep slopes, the trail must be oriented roughly parallel to the contour. Well designed trails on these slopes have the tread sloped to the outside. This allows the water to run off the trail, thereby minimizing erosion and muddiness problems. On steeper slopes, some maintenance will still be required to maintain the slope to the outside so that water on the trail does not gain destructive energy. Increased coarse fragment contents in the soils will make construction more difficult on slopes while generally presenting fewer problems on level sites where no excavation is required. However, stones and large cobbles present more of a problem on level sites because removal of the stones leaves holes which must be filled in by digging holes to get the fill material. On steep slopes the material required is readily available because of the ongoing excavation.

Soil Limitations for Trails as Affected by Flooding

Flooding during the season of use shows more variation in interpretation than any other factor (Table 1 and Appendix A). Interpretations range from flooding once a year during season of use presenting none to slight limitations to flooding at any time during season of use presenting severe limitations for trail use.

Flooding during season of use proved to be difficult to

evaluate by measuring trail response, since very few trails are located in areas which receive more than occasional flooding. Only one section of trail was observed in a flooded state and on the remainder of the trails, it was difficult to correlate response with flooding, since adverse textures and drainages were common in these areas.

Parks personnel indicated that flooding during season of use was undesireable and that sites which are subject to flooding should be avoided if at all possible. Their feeling was that flooded trails are unuseable (Plate 6) and wet conditions resulting in a high susceptibility to damage would be present resulting from high water tables immediately after the flooding. As well, changing stream channels may completely remove portions of these trails. Thus, sites which receive annual or semi-annual floods are rated as having severe limitations for trail use and no flooding during season of use is required for a none to slight limitation rating. Sites which receive infrequent (5 to 10 years apart) floods for short periods are rated as having moderate limitations for trail use. These guidelines are shown in Table 20.

Table 20. Guidelines for Assessing Limitations for Trails Resulting from Flooding

	Degree of Limitation		
	None to Slight	Moderate	Severe
Flooding	None	Occasional (5-10 years apart)	Frequent (1-2 years apart)

Plate 6. Flooding resulting from high water in adjacent McArthur Creek (Yoho). This portion of this trail is unuseable at this time.

The designations as to the frequency of flooding permitted for each grouping are rather general and may vary with the trail objectives. Trails which will receive high amounts of use for the entire season of use will be more affected by flooding than trails which receive low amounts of use or use which occurs after the period of flooding.

Trails on soils with medium and fine tread textures will be more affected by wet conditions after flooding than will trails with coarse textured treads. The amount of use immediately after flooding will also determine the amount of damage.

Soil Limitations for Trails as Affected by Landform and Parent Materials

Landforms and/or parent materials have been correlated with trail deterioration in several trail studies (Root and Knapik, 1971; Helgath, 1975; Roemer, 1975). To evaluate the relationship between parent materials and trail response, observations of trails on outwash, alluvium, and till were compared on well drained sites with no flooding or seepage, sandy loam, fine sandy loam, or loam textures, less than 50 percent gravel, less than 10 percent cobbles; stoniness 0 to 2; no rockiness, elevations less than 1,820 m (6,000 ft) ASL and tread slopes less than 15 percent. A listing of the sites used and details of the statistical analysis are given in Appendix F-7. The results of the analysis of variance are shown below in Table 21. The mean responses are not significantly different at the 5 percent confidence level so Duncan's New Multiple Range Test is not carried out.

Table 21. Results[1] of the Analysis of Variance Assessing the Influence of Parent Materials on Trail Response

Parent Materials	Outwash	Alluvium	Till
Mean Responses	1.00	1.14	1.22

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

Discussion

These results show that trail response does not vary significantly among the three types of parent materials tested, as long as texture, drainage, etc. are kept constant. Since these three types of parent materials correspond to glaciofluvial, fluvial, and morainal landforms, it is also anticipated that trail response would not vary significantly with differing landforms when soil properties are kept constant. These results suggest that the correlation between trail response and landforms or parent materials which has been observed by other authors is due to soil properties such as texture and drainage varying with the landforms or parent materials, rather than due to inherent properties of the landforms or parent materials themselves. Any such differences which do exist among landforms or parent materials would further be minimized by the effects of pedogenesis which is active within the depths of material concerned in this study. Thus, when specific information such as texture and drainage is used, parent materials and landforms are redundant and so are not included in the guidelines for assessing soil limitations for trails. It is recognized

though that parent materials and landforms do provide information to people who are unfamiliar with soils and that they may be useful at a more general level.

Soil Limitations for Trails as Affected by Site Aspect

Aspect might be expected to influence trail response in that south and west facing aspects would tend to be drier and have an earlier snowmelt date than north and east facing slopes, because of the greater amounts of effective solar radiation which they receive.

The influence of aspect on trail response was evaluated by comparing observations of trail response on W, SW, S, SE, E, and NE facing aspects on well drained sites with no flooding or seepage, silt loam textures with less than 50 percent gravel, less than 10 percent cobbles, stoniness 0 to 2, no rockiness, and tread slopes less than 15 percent. Silt loam textures were chosen for this comparison because it was expected that differences in moisture regime resulting from aspect would be the most evident on medium textured soils. A listing of the sites used in this comparison and details of the statistical analysis are shown in Appendix F-8. The results of the analysis of variance are shown below in Table 22. The mean responses are not significantly different at the 5 percent confidence level so Duncan's New Multiple Range Test is not carried out.

Discussion

These results show that aspect does not cause significant changes in trail response even when the comparison is made on silt loam textures where the moisture regime is felt to be most important to trail

Table 22. Results[1] of the Analysis of Variance Assessing the Influence of Site Aspect on Trail Response

Aspects	S	SW	N	E	NE	SE
Mean Responses	1.42	1.57	1.67	1.73	1.80	1.93

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

response. Thus, the influence of aspect on trail response is not considered to be great enough to include aspect as a criterion for determining soil limitations for trails.

South and southwest facing aspects do appear to show a slightly better response though than northeast and east facing aspects, so aspect could be used in the final evaluation of alternatives during the trail planning process. Aspect is particularly important at higher elevations where aspect influences the length of season of use as shown in Plates 7 and 8. The trail on the southwest facing aspect is snow-free and dry while the trail on the northeast facing aspect is still completely unuseable for hikers. Thus, while aspect can not be considered as a major item affecting use of soils for trails, it does appear to have some effect, particularly at higher elevations.

Soil Limitations for Trails as Affected by Position on Slope

Position on slope might be expected to influence trail response in that lower slopes would have a slightly wetter moisture

Plate 7. Helen Lake trail (Banff) at 2240 m (7350 ft) is free from snow and dry on southwest facing aspect on July 6, 1976. Note glacier lilies in bloom.

Plate 8. Near continuous snow cover on northeast facing aspect on opposite valley side from trail shown in Plate 7.

regime than upper slopes. The influence of the position on slope was evaluated by comparing observations of trail response on crest, upper slopes, middle slopes, and lower slopes. The standard conditions chosen were well drained sites with no flooding or seepage, silt loam textures with less than 50 percent gravel, less than 10 percent cobbles; stoniness 0 to 2, no rockiness and tread slopes less than 15 percent. Silt loam textures were used for the comparison because it was expected that differences in moisture regime due to position on slope would have the most effect on silt loam textured sites. No observations of trails in depressions and only two observations of trails on toe positions were available with the above conditions, so these two positions were not included in the comparison. A listing of the sites used and details of the statistical analysis are given in Appendix F-9. The results of the Duncan's New Multiple Range Test are shown in Table 23.

Table 23. Results[1] of Duncan's New Multiple Range Test Assessing the Influence of Position on Slope on Trail Response

Position on Slope	Crest	Lower	Middle	Upper
Mean Responses	1.00	1.63	1.66	2.14

[1] Any two means which are not underscored by the same line are considered to be significantly different at the 5% confidence level.

Discussion

These results show that for trails on silt loam textures, trail response is significantly better on crest position than on upper, middle,

or lower slopes. However, trails on upper slopes show poorer average responses than trails on lower or middle slopes, rather than average responses similar to trails on crests. Therefore, it seems doubtful that trail response can be correlated very well with position on slope. Furthermore, trails with sandy loam textures and the above soil and site characteristics show good responses regardless of slope position. This indicates that position on slope should not be added to the guidelines table as an item affecting use.

The above results do suggest, however, that trails should be built on crests whenever a choice is available. Also, other observations do indicate that depressions should be avoided due to the drainage problems associated with them and due to the difficulties involved in removing water from the trail tread in depressions.

Soil Limitations for Trails as Affected by Snow Avalanching

Snow avalanching might be considered to influence trail response through disruption of the trail tread or the addition of debris to the trail. Observations made during the course of this study, however, showed no trail response which could be directly attributable to snow avalanching. It is expected that debris clearing would be necessary in some avalanche paths in some years, but none was noted during this study. Thus, avalanching is not considered to be a sufficiently significant item to be included in the guidelines for assessing soil limitations for hiking trail use.

There are, however, several other considerations involved when

building trails on avalanche paths. First, the presence of avalanching may present hazards to cross-country skiers if the trail is also intended for winter use. Secondly, the dense alder thickets which are often associated with avalanche tracks may increase clearing costs and may present hazards in terms of unexpected animal encounters. These problems are not soil problems, and so do not enter into the suitability guidelines, but it is suggested that a footnote be attached to interpretations for map units where snow avalanching is present drawing attention to the presence of the avalanching.

Soil Limitations for Trails as Affected by Bulk Density

Bulk density has been used as a measure of trafficability in the guidelines for assessing soil suitability for trails by Brocke (1970). Soils with bulk densities greater than 1.2 g/cc were considered to have none to slight limitations for trails while soils with bulk densities of less than 1.0 g/cc were considered to have severe limitations for trail use. Soils with low bulk densities were considered to be susceptible to compaction, trampling and erosion.

Compaction of soils in picnic areas and campgrounds is a serious problem in that it restricts vegetation growth (Lutz, 1945; LaPage, 1962; Dotzenko *et al.*, 1967). This is not a problem on trails, however, since all vegetation is removed from the trail tread and some vegetation adjacent to the trail is cleared. Compaction of the trail tread itself was not considered to be an impact by Roemer (1975) and in this study, the soil would have had to have been compacted to a

depth of 5 cm below its original surface before it would have been considered a negative response.

Compaction of the trail tread would decrease the permeability of the trail and thereby could increase erosion potential. However, proper trail design would ensure that little water runs down the trail, thereby minimizing any erosion which might occur.

The above discussion provides the rationale for suggesting that bulk density has little effect on soil suitability for trails. Thus, because of the difficulties involved in making accurate estimates of bulk density (samples would have to be taken at each site to ensure accurate bulk density values) and because Brocke (1970) states that his guidelines are not suitable for extrapolation to other areas, bulk density has not been tested as an item affecting use.

Soil Limitations for Trail Use as Affected by Vegetative Habitat

Helgath (1975) has suggested that vegetative habitat is importantly related to trail erosion. Her study methods suggest, however, that this correlation between trail deterioration and vegetative habitat was really a result of the co-varying soil properties such as drainage, rather than a function of the vegetation itself. Vegetative habitat is often a good indicator of some of the soil properties, but vegetative types do not remain constant over large areas such as the Rocky Mountains. Thus, while vegetation can serve as an indicator of soil characteristics, the soil properties are used as being more broadly definitive for interpretive purposes.

Vegetation type is an important consideration in the trail planning process due to the varying clearing costs associated with different vegetation types. Dense vegetation may also have the effect of increasing human-animal encounters. In these respects, though, vegetation type is not a soil problem and so is not considered in this study.

Soil Limitations for Trails as Affected by Carbonate Content

Rutter (1968) showed that carbonate content was an important factor to consider when making erosion predictions. Erosion is one of the major trail deterioration problems, so it might be expected that carbonate content could be correlated with trail deterioration. However, trails are usually constructed within the portion of the soil where pedogenesis has removed most of the carbonates, and so they are not influenced by the carbonate content. Exceptions to this are Regosolic soils which are usually found on colluvial or alluvial landforms. In the former case, high coarse fragment contents and rapid permeabilities also tend to reduce erosion hazard while in the latter case rapid permeabilities and low angled slopes also reduce erosion hazards. Thus, while carbonate content is an important consideration when evaluating erosion potential of subsoil materials, it has limited value for assessing soil suitability for trails.

REFINED GUIDELINES

The results of the evaluations of individual items affecting soil suitability for trail use have been presented and discussed in the preceeding section. These results are combined in Table 24 to form a complete table of guidelines for assessing soil suitability for trail use. The assumptions on which the guidelines are based, instructions for use of the table, and the limitations of the guidelines are also discussed below.

Assumptions

The following assumptions are basic to the use of the guidelines table:

1. The guidelines make predictions of soil behaviour under defined conditions of use and management. It is assumed that the trails will be built at least 45 cm (18 in) wide, and that obstructions such as cobbles and stones will be removed during construction. It is also assumed that a dry, stable trail tread is desireable and that muddy, dusty, worn or eroded trail treads are undesireable. The guidelines also assume a level of use such as is presently being experienced in areas such as Lake O'Hara or the Lake Louise - Morraine Lake area, i.e., less than 10,000 hikers per season. Hiking and riding trails are not treated separately, but as the design requirements for riding trails are more stringent, a given limitation will be more difficult to overcome.
2. The ratings express relative degrees of limitations. Severe ratings

Table 24. Refined[1] Guidelines for Assessing Soil Limitations for Trails

Item[2] Affecting Use	Degree of Limitation[10]		
	None to Slight	Moderate	Severe
Textural Class[3]	SL, FSL, VFSL, L.	SiL, SiCL, CL, SCL, LS.	S, SC, SiC, C, Organic.
Gravel Content[4]	0 - 50%	> 50%	Not applicable
Cobble Content[5]	0 - 20%	20 - 50%	> 50%
Stoniness[6]	Stones > 2 m apart and cover 3% of surface.	Stones 1 to 2 m apart and cover 3 to 15% of surface.	Stones < 1 m apart and cover 15% of surface.
Wetness[7]	Rapidly, well, and moderately well drained soils. Water table below 50 cm during season of use.	Moderately well drained soils subject to seepage or ponding and imperfectly drained soils. Water table may be above 50 cm for short periods during season of use.	Poorly and very poorly drained soils. Water table above 50 cm and often near surface for a month or more during season of use.
Rockiness[7]	R0, R1.[11] Rock outcrops cover 10% of area.	R2.[11] Rock outcrops cover 10-25% of area.	R3-R5.[11] Rock outcrops cover 25% of the area.
Slope[8]	0 - 15%	15 - 30%	> 30%[9]
Flooding	None	Occasional. May flood once every 5-10 years.	Frequent. Floods annually or semi-annually.

1 The refined guidelines contained in this table are based on results presented and discussed in the previous section.

2 The items affecting use listed in this table are those which have been shown to cause significant differences in trail response. Elevation, aspect, position on slope, and snow avalanching may have also slight affects or influence trail management and should be considered in the final site evaluation. A discussion of the problems associated with each item is found in the Results and Discussion section. Items such as vegetation, fauna, and scenic value are not considered in the guidelines.

3 Texture refers to the soil texture which will form the tread texture. This is the surface texture on level areas but may be a subsurface texture on slopes. Textural classes are based on the less than 2 mm soil fraction (CSSC, 1976). See also Appendix D.

4 Gravel content refers to the percentage of gravel by volume which will be present in the trail tread.

5 Cobble content refers to the percentage of cobbles by volume which will be removed during trail construction.

6 Stoniness refers to coarse fragments > 25 cm in diameter.

7 See also definitions for drainage and rockiness classes in the System of Soil Classification for Canada (CSSC, 1974).

8 Slope in this context refers to the slope of the ground surface, not the slope of the trail tread.

9 Greater than 60% slopes may be rated as having very severe limitations for trail use.

10 The nature of the limitation presented by each item is presented in Results and Discussion.

11 The type of rock outcrop (flat lying vs cliffs), and the orientation of the structure (linear cliffs vs massive blocks) can greatly alter the degree of the limitation. Each site with a Rockiness limitation based on the percent rock outcrop above should be evaluated on its own merits and the degree of limitation should then be modified appropriately if necessary.

do not imply that a site cannot or should not be used for trails, but they do indicate greater construction costs, higher design requirements, or a greater susceptibility to environmental impact. The use of soils rated as severe depends on available alternatives and whether or not the soil limitation can be altered successfully and economically within the trail objectives.

3. Interpretations based on soil maps do not eliminate the need for on-site evaluations. The importance of on-site investigations depends on the level of information provided by the soil map and on the nature of the soil problem involved. The same guidelines can be used for on-site investigations as are used for interpreting soil maps.
4. The guidelines are based on soil-related criteria. They do not consider vegetation, scenic qualities, faunal aspects or social carrying capacity, and as such are not intended as final evaluations of site suitability, but rather as predictions of soil behaviour.

Instructions for Use of Guidelines Table

The table of guidelines for assessing soil suitability for trails is intended for use at two levels. First, it is intended to be used for interpretation of soil survey information, and secondly, it can be used to interpret soil properties when making site-specific field observations. The mechanics of the use of the table is the same in both cases.

To use the table, the textural class, gravel and cobble contents, stoniness, wetness, rockiness, slope and frequency of flooding

should be known for the map unit or site under consideration, since all eight of these characteristics influence soil suitability for trails. The relative degree of limitation caused by each item may then be obtained from the guidelines table and all moderate and severe limitations should be recorded. For example, an imperfectly drained site with no flooding, no rockiness, stones 10 m apart, SiCL texture with 30 percent gravel and 5 percent cobbles which occurs on a 40 percent slope would have a severe limitation due to slope and moderate limitations due to wetness and texture. It is important that all the limitations of a map unit for a site be recorded since the response on the above site would be different than the response on a site with no wetness or textural limitation, even though both have severe limitations resulting from slopes. Thus, all the limitations of a site must be considered and it is not enough to simply rate the soil as slight, moderate, or severe according to the severest limitation present. A format of presentation of the interpretations similar to that of Coen and Holland (1976) is recommended. This format is shown in Table 25 using the above two examples and a third soil with no limitations.

Table 25. Suggested Format for Presentation of Interpretations

	Degree and Nature of Limitation		
Map Unit	None to Slight	Moderate	Severe
XYZ 1		Wetness, Texture	Slope
XYZ 2			Slope
XYZ 3	Nil		

This format has the advantage that it shows all of the limitations which are present for a given map unit or site, and by referring to the discussion of the individual items, the exact nature of the problems likely to be encountered at that site is given. This allows a complete and accurate evaluation of the relative merits and limitations of the soils at each site. Interpretations made in this manner are more complex than a simple slight, moderate, or severe rating as has been used in some reports, but the interpretations made in this manner should be more meaningful since this way gives an understanding of the nature of the problems involved with the use of that site.

Limitations of the Interpretations

The accuracy or reliability of the interpretations of soil limitations for trail use made in the above manner is controlled by several factors. First, the guidelines (Table 24) are based on several assumptions. Where these assumptions do not hold, the interpretations may not be an accurate reflection of the limitations present. Secondly, the guidelines table does not take interactions among the items affecting use into account when assessing the limitations. Where interactions occur, the interpretations will only be as reliable as the interpreters understanding of those interactions. Thirdly, the reliability of the interpretations will be determined by the accuracy of the soils information available. An incorrect diagnosis of the nature of the soil properties present may lead to erroneous interpretations.

The assumptions on which the guidelines table (Table 24) are based have been stated above. Included is the assumption that trails

will be built to certain standards and that muddy, dusty, etc. trail conditions are undesireable. If trail standards or objectives change so that, for example, muddy conditions are acceptable, then the interpretations of texture and wetness will not provide the desired conclusion. Similarly, cobbles and stones would not present a limitation for trail use if a trail tread free of obstacles were not one of the specified attributes. Therefore, the interpretations will lose some of their value when the assumptions about trail standards or the desireability of various trail conditions are not applicable. Also, the guidelines are based on present levels of use because the observations of trail response have been made with present use levels. Trail response could change if the amount of use changed drastically so that the guidelines might then be less applicable than at present.

Interactions among the items affecting use have not been taken into account by the guidelines table (Table 24). These interactions are, however, discussed in the individual sections of soil limitations for trails as affected by the various items. An understanding of the interactions among these items is essential to the making of accurate and reliable interpretations. This is especially important when evaluating the relative merits of sites with several limitations. Aspect and position on slope may also have important interactions with some of the items affecting use and should not be neglected in site evaluations.

The accuracy of the soils information available to the interpreter is perhaps the most important factor determining the reliability of the interpretations of the soils information. Regardless

of how good the guidelines are, the interpretations can be no better than the soils information upon which they are based.

Soils information is presently available or being gathered at several levels of detail within the Mountain National Parks. Within the study area, Waterton Lakes National Park was mapped at a scale of 1:15,840; Yoho National Park was mapped at a scale of 1:25,000; and Banff National Park is being mapped at a scale of 1:50,000. As mapping scale decreases, the size (on the ground) of the smallest delineation that can be made on the map increases from about 2.5 hectares (10 ac) at 1:15,840 to 25 hectares (100 ac) at 1:50,000. This increase in the minimum size of map unit delineation necessitates broader map unit concepts with a corresponding loss of detail and greater soil variability within the map units. Thus, while map units in Waterton and Yoho usually have soils which are defined within single drainage and textural classes, map units in Banff are defined as having soils with a range of textures and inclusions of sub-dominant drainages. Interpretations based on the large-scale map units in Waterton and Yoho will therefore be more reliable than those based on small-scale map units such as in Banff.

This limitation of the interpretations due to the level of information provided on the soil maps can, however, be overcome by making site specific investigations of the soils along proposed trail routes. These site-specific evaluations should be made in any case, but are relatively more important in areas where soils information is absent or provided at a general level.

CONCLUSIONS

A number of soil characteristics are shown to have an important influence on limitations of sites for trail use. Soil textural class, gravel content, cobble content, stoniness, wetness, rockiness, slope and susceptibility to flooding may individually or in combination present limitations to the use of soils for trails. Guidelines for assessing the limitations due to the above items have been presented in Table 24. A discussion of the nature of the limitations imposed by each item and an indication of possible interactions among items is included in the Results and Discussion section.

Elevation, aspect, position on slope, and snow avalanching did not cause significant variations in trail response with the test conditions used in this study. As such, they have not been included in Table 24 as items affecting use. They do, however, represent important considerations in final site evaluations and may have important interactions with other items affecting use. A discussion of the possible influences of each of these items has been included in the Results and Discussion section.

A consideration of landforms, parent materials, and vegetative habitats can provide much useful information about soil limitations for trail use. However, important soil characteristics such as texture and drainage do not remain constant on similar landforms within an area as large as the National Parks in the Rocky Mountains and vegetative habitats change in response to non-soil related items. Therefore, soils criteria are chosen for use in the guidelines because of the wider applicability of the soil criteria.

The guidelines presented in Table 24 may be used to interpret soil maps or to interpret site-specific observations. The instructions provided for use of the guidelines table are equally applicable to both situations. A suggested format for presentation of the interpretations is provided in Table 25. It should be noted that the guidelines for assessing soil limitations for trails are based on certain stated assumptions. As long as these assumptions apply, interpretations made according to the guidelines should be accurate and reliable. It should also be noted that the interpretations can be no better than the soils information on which they are based. Thus, accurate soils information is essential to making reliable interpretations. Definitions of the textural classes are provided in Appendix D to make identification of the textural classes in the field easier for laymen.

It is anticipated that the refined guidelines for assessing soil limitations for trails (Table 24) and the accompanying instructions and discussions will allow for more reliable and useful interpretations of soil-related criteria by both professionals and laymen. It is also anticipated that these interpretations will be useful as a part of the process of determining where trails should be located and how they should be built in order to meet the objectives of environmental preservation and user satisfaction.

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APPENDIX A

Examples of Previously Published Guidelines for Assessing Soil Suitability for Trails

Appendix A-1. Table IV from Brocke (1970).

Soil Limitations for Hiking Trails

Soil Property Affecting Use	Degree of Soil Limitation			
	None	Slight	Moderate	Severe
Wetness	Well drained soils with water table below 3 feet	Moderately-well drained soils with water table below 3 feet	Imperfectly drained soils with water table 1 to 3 feet	Poorly drained and very poorly drained soils
Susceptibility to flooding	None during season of use	None during season of use	1 or 2 floodings during season of use	More than 2 floodings during season of use
Slope gradient	0 - 9%	9 - 15%	15 - 30%	> 30%
Surface stoniness	Class 0	Classes 1 and 2	Class 3	Classes 4 and 5
Surface soil texture	SL, FSL, and VFSL	L	SiL, SiCL, SCL, CL, SC, SiC, C, and LS	Sand, organic soils, subject to severe wind erosion
Trafficability	Surface bulk density greater than 1.2 g/cc when underlying material is greater than 1.3 g/cc	Surface bulk density greater than 1.2 g/cc	Surface bulk density 1.0 to 1.2 g/cc	Surface bulk density less than 1.0 g/cc

Appendix A-2. Table 9 from Coen and Holland (1976).

Guide for Assessing Soil Limitations for Paths and Trails

This guide applies to soils to be used for local and cross-country footpaths and trails and for bridle paths. It is assumed that these areas will be used as they occur in nature and that little or no soil will be moved (excavated or filled). The steeper the slope upon which a trail is to be built the more soil that will have to be moved to obtain a level tread and the more miles of trail needed to cover a given horizontal distance. Severe limitation does not indicate a trail can not or should not be built. It does suggest higher design requirements and higher cost of construction and maintenance. Soil features that affect trafficability, dust, design, and maintenance of trafficways are given special emphasis.

Item Affecting Use	Degree of Soil Limitation[8]		
	None to Slight	Moderate	Severe
Wetness (Wet)[1]	Rapidly, well, and moderately well drained soils; water table below 20 in. during season of use	Imperfectly drained soils; water table during season of use may be above 20 in. for short periods	Poorly and very poorly drained soils; water table above 20 in. and often near surface for month or more during season of use
Flooding (Flood)	May flood once a year during season of use	May flood 2 or 3 times during season of use	Floods more than 3 times during season of use
Slope[2] (Slope)	0-15% (AE)	15-30% (F)	30-60%[3] (G)
Surface soil texture[4] (Text)	SL, FSL, VFSL, L, SiL	CL, SCL, SiCL, LS	SC, SiC, C, sand, organic soils
Coarse fragments on surface[5] (CF)	0 - 20%	20 - 50%[6]	> 50%
Rockiness or stoniness[7] (Rock)	Stones greater than 25 ft apart; rock exposures roughly 100 ft apart and cover less than 10% of the surface	Stones 5-25 ft apart; rock exposures 30-100 ft apart and cover 10-25% of the surface	Stones less than 5 ft apart; rock exposures less than 30 ft apart and cover more than 25% of the surface

1 The abbreviations in brackets are used in Table 10 to indicate the nature of the limitation.

2 Slope in this context refers to the slope of the ground surface, not the slope of the tread of the trail.

3 A distinction between severe limitation (30-60%) and very severe limitation (greater than 60%) will be made in the interpretation table (Table 10).

4 Surface texture influences soil ratings as it affects foot trafficability, dust, design, or maintenance of paths and trails.

5 Soils on steep colluvial slopes and alluvial fans often do not profide a significant limitation to trails other than coarse fragments and slope. However, this is in part a result of their low bulk density and extreme permeability which does not normally allow any surface runoff of water. If some act of nature or man should result in a significant flow of water down the trail, these soils will erode very quickly, forming deep gullies. Soils on steep till slopes may have the same limitations as the above soils according to Table 10 but will not erode as badly if water is diverted down the trail.

6 Some gravelly soils may be rated slight if the content of the gravel exceeds 20% by only a small margin providing (a) the gravel is imbedded in the soil matrix or (b) the fragments are less than 3/4 inch in size.

7 See also definitions for gravels, rockiness, and stoniness in The System of Soil Classification for Canada (C.S.S.C., 1970), pp. 213-214. Coarse fragments include both gravels and cobbles.

8 A fourth degree of soil limitation is also defined for the purposes of Table 10 -- Unsuitable: Permanently wet soils; floods more than 4 times during season of use; rock outcrop too frequent to permit location of paths and trails.

Appendix A-3. Table 6 from Knapik and Coen (1974).

Guides for Assessing Soil Limitations for Trails

This guide applies to soils to be used for trails assuming no hard surfacing. It is assumed that these areas will be used as they occur in nature and that little or no soil will be moved (excavated or filled). The steeper the slope upon which a trail is to be built the more soil that will have to be moved to obtain a level tread and the more miles of trail needed to cover a given horizontal distance. Severe limitation does not indicate a trail can not or should not be built. It does suggest higher design requirements, higher cost of construction and maintenance, and often greater potential for environmental impact. Soil features that affect trafficability, dust, design and maintenance of trails are given special emphasis.

Items Affecting Use	Degree of Soil Limitation		
	None to Slight	Moderate	Severe
Wetness	Rapidly, well and moderately well drained soils. Water table below 20" during season of use.	Imperfectly drained soils. Water table during season of use may be above 20" for short periods.	Poorly and very poorly drained soils. Water table above 20" and often near surface for month or more during season of use.
Flooding	Does not flood.	May flood but not during season of use.	Floods during season of use.
Slope[1]	0 - 15% (AE).	15 - 30% (F).	Greater than 30%[2] (F).
Surface soil texture[3] (Text.)	SL, FSL, VFSL, L.	SiL, CL, SCL, SiCL, LS.	SC, SiC, C, sand, peaty and organic soils.
Coarse fragments on surface (CF)	0 - 20%.	20 - 50%.[4]	>50%.
Rockiness or stoniness[5] (Rock)	Stones greater than 25' apart. Rock exposures roughly 100' apart and cover less than 10% of the surface.	Stones 5 to 25' apart. Rock exposures 30 to 100' apart and cover 10 to 25% of the surface.	Stones less than 5' apart. Rock exposures less than 30' apart and cover more than 25% of the surface.

[1] Slope in this context refers to the slope of the ground surface, not the slope of the tread of the trail.

[2] A distinction between severe limitation (30 to 60%) and very severe limitation (greater than 60%) will be made in the interpretation table (Table 10).

[3] Surface texture influences soil ratings as it affects food trafficability, dust, design or maintenance of trails, and erosion hazard. Most of these textures are not applicable to this specific area.

[4] Some gravelly soils may be rated slight if the content of the gravel exceeds 20% by only a small margin providing (a) the gravel is embedded in the soil matrix or (b) the fragments are less than 3/4 inch in size.

[5] See also definitions for gravels, rockiness and stoniness in the System of Soil Classification for Canada (C.S.S.C., 1970), pp. 213-214. Coarse fragments include both gravels and cobbles.

Appendix A-4. Table 8 from Greenlee (1976).

Guides for Developing Soil Interpretations for Paths and Trails

Properties Affecting Use	Degree of Limitation		
	None to Slight	Moderate	Severe
Flooding	Not subject to flooding during season of use.	May flood 1 or 2 times during season of use.	Subject to flooding more than 2 times during season of use.
Wetness[1] (soil drainage)	Very rapidly, rapidly, well and moderately well drained soils. Water table below 20 in. during season of use.	Moderately well drained soils subject to occasional seepage or ponding, and imperfectly drained soils. Water table may be above 20 in. for short periods during season of use.	Poorly and very poorly drained soils. Water table above 20 in. and often near the surface for a month or more during season of use.
Slope[2]	0 to 15% (aA - eE)	15+ to 30% (fF)	Greater than 30% (gG - hH)
Surface stoniness[3]	0 to 2	3	4 and 5
Rockiness[4]	Rock exposures roughly 100 ft. (30 m) apart and cover less than 10% of the surface.	Rock exposures 30 to 100 ft. (10-30 m) apart and cover 10 to 25% of the surface.	Rock exposure less than 30 ft. (10 m) apart and cover more than 25% of the surface.
Surface soil[5] texture	SL, FSL, VFSL and L.	SiL, SiCL, SCL, CL and LS.	SC, SiC, C, sand and soils subject to severe blowing. All very gravelly, very cherty, very cobbly and very channery soils. Organic soils.

[1] See definitions of soil drainage classes in Glossary.

[2] Slope in this context refers to the slope of the ground surface, not the slope of the tread of the trail. Soil erodibility is an important item to consider in rating this limitation. Some adjustments in slope range may be needed in different climatic zones.

[3] See definitions of surface stoniness in section entitled "General Discussion of Soil Map".

[4] See definitions of rockiness in The System of Soil Classification for Canada (CDA, 1974).

[5] In regions of arid or subhumid climate, some of the finer textured soils may be rated one class better. See definitions of soil textural classes in Glossary.

Appendix A-5. Table 7 from Vold (1975).

Soil Limitations for Trails for Yoho Valley

Soil Property Affecting Use	Degree of Soil Limitation		
	Slight	Moderate	Severe
Drainage Class*	Well to moderately well drained.	Imperfectly drained.	Poorly to very poorly drained.
Flooding	None.	Light floods can occur every 3 - 4 years.	Floods during each season of use.
Slope	0 - 15% (A to E)	15 - 60% (E to G)	60% + (H)
Texture*	SL, FSL, L	SiL, LS	S, Si, C, organic
Coarse Fragments*	10 - 50%	0 - 10%; 50 - 75%	75% +
Rockiness	Rock exposures cover less than 20% of area.	Rock exposures cover from 20 - 50% of area.	Rock exposures cover greater than 50% of area.
Elevation	Less than 6,500 feet.	Greater than 6,500 feet.	N.A.

* See Canada, Department of Agriculture (1974) for definitions.

Appendix A-6. Table A-1 from Deeg (1976).

Considerations for Assessing Soil Limits for Trails

These considerations apply to soils to be used for trails assuming no hard surfacing. It is assumed that these areas will be used as they occur in nature and that little or no soil will be moved (excavated or filled). The steeper the slope upon which a trail is to be built the more soil that will have to be moved to obtain a level tread and the more miles of trail needed to cover a given horizontal distance. Severe limitation does not indicate a trail can not or should not be built. It does suggest higher design requirements, higher cost of construction and maintenance, and often greater potential for environmental impact (Knapik and Coen, 1974; 71).

Soil Characteristic Factors Affecting Use	Degree of Soil Limitation		
	None to Slight	Moderate	Severe
Wetness	Rapidly, well and moderately well drained soils. Water table below 20" during season of use.	Imperfectly drained soils. Water table during season of use may be above 20" for short periods.	Poorly and very poorly drained soils. Water table above 20" and often near surface for month or more during season of use.
Flooding	Does not flood.	May flood but not during season of use.	Floods during season of use.
Slope[1]	0 to 15%	15 to 30%	Greater than 30%
Surface soil texture[2]	SL[3], FSL, VFSL, L.	SiL, CL, SCL, SiCL, LS.	SC, SiC, C, sand, peaty and organic soils.
Coarse fragments on surface (CF)	0 to 20%.	20 to 50%[4].	>50%.
Rockiness or stoniness[5] (Rock)	Stones greater than 25' apart. Rock exposures roughly 100' apart and cover less than 10% of the surface.	Stones 5 to 25' apart. Rock exposures 30 to 100' apart and cover 10 to 25% of the surface.	Stones less than 5' apart. Rock exposures less than 30' apart and cover more than 25% of the surface.

1 Slope in this context refers to the slope of the ground surface, not the slope of the tread of the trail.

2 Surface texture influences soil ratings as it affects food trafficability, dust, design or maintenance of trails, and erosion hazard. Most of these textures are not applicable to this specific area.

3 Expanded Abbreviations for: S - sandy; L - loam; F - fine; VF - very fine; Si - silt; C - clay; (e.g., SL - sandy loam).

4 Some gravelly soils may be rated slight if the content of the gravel exceeds 20% by only a small margin providing (a) the gravel is embedded in the soil matrix or (b) the fragments are less than 3/4 inch in size.

5 See also definitions for gravels, rockiness and stoniness in the System of Soil Classification for Canada (C.S.S.C., 1974, pp. 218-219). Coarse fragments include both gravels and cobbles.

APPENDIX B

A Summary of the Field Observation Data

Abbreviations

The abbreviations used in this Appendix are as follows:

Map Units:

AL	Altrude	OH	Ohara
BG	Burgess	OL	Ottertail
BK	Baker Creek	OO	Otto
BT	Bath	PL	Peyto Lake
CM	Cathedral	PR	Panarama Ridge
CO	Clawson	R	Rock
DS	Dennis	SC	Stream Channel
HR	Hagarth	SK	Shaffer
KI	Kicking Horse	TA	Takkakaw
LV	Larch Valley	TO	Tocher
ML	Morraine Lake	VA	Vanguard
MP	Molar Pass	WR	Watchtower
OG	Ogden		

A is also used as a modifier indicating avalanching.

Refer to Soil Survey of Yoho National Park, B. C. (Coen, Epp, and Tajek, 1977); Biophysical Land Classification of Banff National Park, Progress Report No. 2, 1975-1976 (Walker, Kojima, Coen, and Holland, 1976); and Soils of Waterton Lakes National Park (Coen and Holland, 1976) for map unit descriptions.

Position on Slope:

Dep	Depression
Low	Lower
Mid	Middle
Up	Upper
Cres	Crest

Classification:

BGL	Brunisolic Gray Luvisol
CR	Cumulic Regosol
DBC	Dark Brown Chernozem
DDB	Degraded Dystric Brunisol

DEB	Degraded Eutric Brunisol
GMB	Gleyed Melanic Brunisol
GOEB	Gleyed Orthic Eutric Brunisol
GOR	Gleyed Orthic Regosol
GR	Gleyed Regosol
GTMB	Gleyed Turbic Melanic Brunisol
GTSHFP	Gleyed Turbic Sombric Humo Ferric Podzol
LOEB	Lithic Orthic Eutric Brunisol
LR	Lithic Regosol
LSHFP	Lithic Sombric Humo Ferric Podzol
ODB	Orthic Dystric Brunisol
OEB	Orthic Eutric Brunisol
OFHP	Orthic Ferro Humic Podzol
OG	Orthic Gleysol
OHFP	Orthic Humo Ferric Podzol
OMB	Orthic Melanic Brunisol
OR	Orthic Regosol
RG	Rego Gleysol
SHFP	Sombric Humo Ferric Podzol

Drainage:

M. Well	Moderately Well
Imp	Imperfect
V. Poor	Very Poor

Texture:

CL	clay loam	SiCL	silty clay loam
FSL	fine sandy loam	SiL	silty loam
L	loam	SL	sandy loam
LS	loamy sand		

G and VG are used as gravelly and very gravelly modifiers, respectively.

Parent Material:	All	alluvium		
	Col	colluvium		
	Lac	lacustrine		
	Loes	loess		
	Out	outwash		
	Till	glacial till		
	Un	undiferentiated		

Response:	1	Good	C	loose coarse fragments
	2	Medium	D	dusty
	3	Poor	E	erosion
	4	Very poor	M	muddy
	5	Unuseable	R	roots
			S	stones
			W	worn

	Site											Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
1	TA1	2	0	0	-	-	-	G^F_t	1,180	E		OEB	Well		FSL	5	0	0	Out	2	1
2	TA1	5	1	0	-	-	-	G^F_t	1,180	E		DEB	Well		FSL	0	0	0	Out	2	1
3	OL1	50	1	0	-	-	-		1,200	S	Low	OEB	Well		SiCl	20	0	0	Till	3	1
4	OL1	20	1	0	-	-	-	Mr	1,205	S	Mid	DEB	M. Well		FSL	0	0	0	Till	15	2^E
5	OL1	8	1	0	-	-	-	Mr	1,225	SE	Cres	DEB	Well		L	5	0	0	Till	5	1
6	DS1	5	1	0	-	-	-	Lv/Mi	1,225	SW	Cres	OEB	Well		SiCL	0	0	0	Lac	5	1
7	DS1	10	1	0	-	-	-	Mi	1,230	S	Cres	OEB	Well		SiL	5	0	0	Till	10	1
8	TO1	2	1	0	-	-	-	Ft	1,185			OEB	Well		SiL	5	0	0	All	2	2^W
9	TO1	2	1	0	-	-	-	Ft	1,185			OEB	Well		SiCL	20	0	0	All	2	1
10	TO1	2	1	0	++	-	-	Fl	1,185			OG	Poor	30	SiL	20	0	0	All	2	4^M
11	TO1	3	1	0	+	-	-	Ft	1,185			OR	M. Well	90	VGLS	75	0	0	All	3	1
12	TO1	15	1	0	-	-	-	Lb	1,195	E	Low	OEB	Well		SiL	5	0	0	Lac	5	1
13	TO1	2	1	0	-	-	-		1,195			DEB	Well		SiL	5	0	0		2	2^M_W
14	TO1	5	1	0	-	-	-	Ft	1,190	SE		OEB	M. Well		GSiCL	40	5	0	All	2	2^M
15	TO1	2	1	0	-	-	-	Ft	1,190			OEB	Well		GSiL	25	5	0	All	2	1
16	TO1	2	1	0	+	-	-	Ft	1,195			OR	M. Well		VGSiL	80	0	0	All	2	2^M
17	TO1	5	1	0	-	-	-	Ft	1,195	NE		OEB	Well		SiL	0	0	0	All	2	2^M_W
18	TO1	2	1	0	++	-	-	Fl	1,195			RG	Poor	30	SL	5	0	0	All	2	1
19	KI2	2	1	0	+	-	-	Ft	1,195			GOR	Imp	100	GSiL	25	0	0	All	1	2^M
20	KI2	2	1	0	+	-	-	Ft	1,200			OR	M. Well	100	VFSL	0	0	0	All	2	1
21	KI2	2	1	0	+	-	-	Ft	1,200			GOR	Imp	100	SiL	5	0	0	All	1	1
22	KI2	1	1	0	+	-	-	Fl	1,200			GR	Poor	100	G	95	0	0	All	1	1
23	TO1	2	1	0	-	-	-	Ft	1,200			GOEB	Imp	100	SiL	10	0	0	All	1	1
24	TO1	2	1	0	+	-	-	Ft	1,200			OR	M. Well		SiL	0	0	0	All	2	2^M_W

Site												Soil										
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
25	TO1	2	1	0	–	–	–	Ft	1,200			GOEB	Imp		SiL	10	0	0	All	1	2^{W}_{M}
26	TO1	2	1	0	+	–	–	Ft	1,200			OR	M. Well	80	SiL	0	0	0	All	1	2^{W}
27	CO1	12	2	0	–	–	–	Ff	1,310	E	Low	OEB	Well		FSL	15	0	0	All	5	2^{W}
28	CO1	15	2	0	–	–	–	Ff	1,310	E	Low	OEB	Well		GSiL	30	15	0	All	5	2^{M}_{S}
29	CO1	10	1	0	–	–	–	Ff	1,310	E	Low	OEB	Well		FSL	0	0	0	All	3	1
30	CO1	12	2	0	–	–	–	Ff	1,310	E	Low	OEB	Well		FSL	10	0	0	All	4	1
31	CO1	15	1	0	–	+	–	Ff	1,310	SE	Low	GOEB	Imp	>50	GSiL	30	5	0	All	2	3^{M}
32	CO1	10	2	0	–	–	–	Fl	1,315	SE	Low	OEB	M. Well		SiL	5	0	0	All	3	2^{M}_{W}
33	OL1	8	1	0	–	+	–	Mi	1,330	SE	Low	GOEB	Poor	20	SiL	5	0	0	All	3	5^{M}
34	OL1	12	1	0	–	–	–	Mi	1,325	E	Mid	OEB	Well		SiL	15	0	0	Till	2	1
35	OL1	15	1	0	–	–	–	Mi	1,325	SE	Mid	OEB	Well		GSiL	30	0	0	Till	5	2^{W}
36	OL1	20	1	0	–	+	–	Mi	1,335	SE	Low	GOEB	Imp	40	SiL	10	0	0	Till	3	3^{M}_{W}
37	OL1	15	1	0	–	–	–	Mb	1,335	SE	Mid	OEB	Well		SiL	20	0	0	Till	5	1
38	OL1	15	1	0	–	–	–	Mb	1,325	SE	Low	OEB	M. Well		SiL	10	10	0	Till	12	2^{M}
39	OL1	15	1	0	–	–	–	Mb	1,340	E	Low	OEB	M. Well		SiL	10	10	0	Till	12	3^{E}_{M}
40	OL1	35	1	0	–	–	–	Mb	1,355	E	Mid	OEB	Well		SiL	10	0	0	Till	8	2^{M}
41	OL2 + VA1	10	2	0	–	–	–	Ff	1,355	E	Mid	OEB	M. Well		FSL	10	0	0	All	2	1
42	OL2 + VA1	15	2	0	–	–	–	Ab/Mb	1,350	E	Mid	OEB	Well		L	10	0	0	All	10	2^{M}
43	OL2 + VA1	12	1	0	–	–	–	Ab	1,180	SE	Low	OEB	Well		GL	40	5	0	All	8	1
44	OL2 + VA1	5	0	0	–	+	–	Fb	1,165	S	Mid	OG	V. Poor	20	SiL	0	0	0	All	2	5^{M}
45	TA1	2	1	0	–	–	–	G^{F}_{t}	1,270	S		DEB	Well		L	15	0	0	Out	2	1
46	TA1	2	1	0	–	–	–	G^{F}_{t}	1,270			DEB	Well		FSL	1	0	0	Out	2	1
47	TA1	3	1	0	–	–	–	G^{F}_{t}	1,270			OEB	Well		FSL	10	0	0	Out	2	1
48	TA1	12	1	0	–	–	–	G^{F}_{r}	1,255	S	Mid	OEB	Rapid		VGSL	75	0	0	Out	12	1
49	OL1	10	0	0	–	–	–	Lt	1,130	NE	Mid	OEB	M. Well		SiCl	2	0	0	Lac	2	2^{M}

Site												Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
50	OL1	50	1	0	-	-	-	Ms	1,135	E	Low	OEB	Well		GSiCL	45	0	0	Col	10	1
51	OL1	35	1	0	-	-	-	Ms	1,145	E	Mid	OEB	Well		GSiL	40	0	0	Col	12	1
52	OL1	35	2	2	-	-	-		1,150	SE	Mid	OEB	Well		GL	40	5	0	Col	12	1
53	CO1	5	1	0	-	-	-	Ff	1,310	E	Mid	OEB	M. Well		SiL	0	0	0	All	3	2^{M}
54	CO1	12	1	0	-	-	-	Ff	1,315	E	Mid	OEB	M. Well		GSiL	20	5	0	All	12	3^{E}_{M}
55	CO1	15	1	0	-	-	-	Ff	1,325	E	Mid	OEB	M. Well		GSiL	20	5	0	All	12	2^{E}
56	CO1	15	3	0	-	-	-	Mi	1,330	E	Mid	OEB	M. Well		GL	20	10	10	Till	12	3^{S}_{E}
57	CO1	40	2	0	-	-	-	Ms	1,350	E	Mid	OEB	Well		GL	30	10	5	Till	40	3^{E}
58	CO1	20	3	0	-	-	-	Mi	1,360	E	Mid	OEB	Well		L	20	0	0	Till	5	2^{S}
59	CO1	20	1	0	-	-	-	Av/Mi	1,365	E	Mid	OEB	Well		SiL	20	0	0	All	12	2^{E}
60	CO1	12	3	0	-	-	-	Mv	1,380	E	Mid	OEB	M. Well		VGSiL	30	15	10	Till	12	3^{E}_{S}
61	OL1	60	2	0	-	-	-	Cb	1,410	E	Mid	OEB	Well		VGSL	80	0	0	Col	30	2^{C}
62	OL1	40	1	0	-	-	-	Ms	1,425	NE	Mid	OEB	Well		SiL	10	0	0	Till	5	2^{E}_{W}
63	OL1	45	2	0	-	-	-	Ms	1,450	E	Mid	OEB	Well		SiL	15	0	0	Till	30	2^{E}
64	OL1	65	4	2	-	-	-	Cv	1,465	E	Up	OR	Rapid		GL				Col	30	3^{S}_{E}
65	OL1	35	1	4	-	-	-	Cv	1,480	E	Up	OEB	Well		SiL	10	5	0	Col	2	1
66	OL1	15	1	0	-	-	-	Mi	1,100	S	Low	OEB	M. Well		SiCL	15	0	0	Till	12	1
67	OL1	15	1	0	-	-	-	Mi	1,135	S	Low	GOR	Imp		L	15	0	0	All	15	2^{W}
68	OL1	8	1	0	-	+	-	Mi	1,145	S	Low	GOR	Imp		SiL	15	0	0	Till	8	4^{R}
69	OL1	12	1	0	-	-	-		1,160	SE	Cres	OEB	Well		SiCL	5	0	0	Un	12	2^{E}
70	OL1	25	3	0	-	-	-		1,165	SE	Cres	OEB	Well		SiL	5	5	5	Un	25	2^{M}_{E}
71	HR1	5	0	0	-	-	-	G^{F}_{1}	1,590			OEB	M. Well		SiL	5	0	0	Out	1	2^{M}
72	HR1	5	0	0	-	-	-	G^{F}_{1}	1,590			OEB	Well		SL	5	0	0	Out	3	1
73	HR1	4	2	0	-	-	-	G^{F}_{1}	1,590			OHFP	Well		SL	5	0	0	Out	2	1

Site												Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Trend Slope %	Response[9]
74	HR1	1	1	0	-	-	-	G^F_1	1,590			DEB	Well		FSL	0	0	0	Out	1	1
75	HR1	2	1	0	-	-	-	G^F_1	1,590			OEB	Well		SL	5	0	0	Out	2	1
76	HR1	5	2	0	-	-	-	Ff	1,590			OEB	Well		SiL	5	0	0	All	5	1
77	HR1	6	2	0	-	-	-	Ff	1,590			OHFP	M. Well		FSL	5	0	0	All	3	1
78	CM1	20	3	1	-	-	-	Mv	1,600	NW	Low	OEB	Well		GSL	25	0	0	Till	20	3^E_C
79	CM1	15	0	3	-	-	-	Mv	1,605	NW	Mid	LOEB	Well		L	0	0	0	Till	15	3^E_M
80	CM1	12	0	4	-	-	-	Mv	1,610	NW	Mid	LOEB	Well		L	0	0	0	Till	12	2^M
81	CM1	16	0	4	-	-	-	Mv	1,615	NW	Mid	LOEB	Well		L	0	0	0	Till	16	3^C
82	OG1 + R	40	4	2	-	-	-	Cv	1,585	E	Low	OEB	Well		VGSiL	20	20	20	Col	17	3^S_E
83	OG1 + R	65	4	0	-	-	-	Cs	1,590	E	Low	OEB	Well		GSiL	20	20	10	Col	28	2^S
84																					
85	OG1 + R	65	3	0	-	-	-	Cs	1,605	E	Mid	OEB	Well		GSiL	35	10	5	Col	25	3^S_E
86	OG1 + R	30	3	2	-	-	-	Mv	1,615	E	Mid	OHFP	M. Well		SiL	10	5	5	Till	17	3^E_S
87	OG1 + R	25	3	3	-	-	-	Mv	1,650	E	Dep	OEB	M. Well		SiL	5	5	5	Till	15	3^M_W
88	OG1 + R	5	2	3	-	+	-	Mv	1,635	S	Dep	OEB	M. Well		SiCL	5	5	0	Till	5	4^M
89	OG1 + R	2	1	3	-	+	-	Mv	1,635			OEB	M. Well		SiL	5	0	0	Till	2	2^M_W
90	OG1 + R	1	1	3	-	+	-	Mv	1,635			OEB	Imp	20	SiCL	0	0	0	Till	1	3^M
91	OG1 + R	15	1	0	-	-	-	Mv	1,635	NE	Low	OEB	M. Well		SiL	5	0	0	Till	8	3^M
92	OG1 + R	5	2	1	-	-	-	Mv	1,635			OEB	M. Well		SiL	10	0	0	Till	3	2^M
93	OG1 + R	10	1	0	-	-	-	Mv	1,630	N	Mid	OEB	M. Well		SiL	5	0	0	Till	5	3^M
94	OG1 + R	5	2	0	-	-	-	Mv	1,630	W	Up	DEB	Well		SiL	5	0	0	Till	5	2^M
95	OG1 + R	2	1	0	-	-	-	Mv	1,630			OEB	M. Well	10	SiCL	5	0	0	Till	2	3^M
96	CM1	75	3	0	-	-	-	Ms	1,730	E	Up	OEB	Rapid		VGSL	60	10	2	Till	15	2^S
97	CM1	10	2	0	-	-	-	Mr	1,740	S	Cres	DEB	Rapid		FSL	15	0	0	Till	10	2^S
98	CM1	8	2	0	-	-	-	Mr	1,745			OEB	Well		FSL	0	0	0	Till	8	1

Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
	Site											Soil									
99	CM1	30	2	0	-	-	-	Mi	1,755	N	Up	DEB	Well		L	15	5	0	Till	8	1
100	CM1	40	2	0	-	-	-	Mi	1,760	SE	Up	OEB	Well		L	0	0	0	Till	15	1
101	CM1	6	2	0	-	-	-	Mi	1,770	N	Mid	DEB	Well		L	0	0	0	Till	5	1
102	CM1	5	1	0	0	0	0	G_1^F	1,775	N	Mid	DEB	Well		FSL	10	0	0	Out	5	1
103	CM1	5	1	0	-	-	-	Li	1,780	S		OEB	Well		CL	5	0	0	Lac	2	2^W
104	CM1	25	2	0	-	-	-		1,775	SE	Mid	OEB	Well		L	10	5	0	Till	10	1
105	TA1	4	2	0	-	-	-	G_1^F	1,775	S	Mid	DEB	Well		SL	2	0	0	Out	2	1
106	TA1	2	1	0	-	-	-	G_1^F	1,775			DEB	Rapid		FSL	5	0	0	Out	2	1
107	TA1	2	1	0	-	-	-	G_1^F	1,775			OHFP	Rapid		FSL	5	0	0	Out	2	1
108	TA1	2	2	0	-	-	-	G_u^F	1,775			DEB	Well		SiL	5	0	0	Out	2	2^M
109	TA1	3	2	0	-	-	-	G_u^F	1,775			OEB	Rapid		GSL	30	15	0	Out	3	2^S
110	TA1	4	3	0	-	-	-	G_u^F	1,775			DEB	Rapid		VGSL	50	20	5	Out	3	2^S
111	AL1	15	3	0	-	-	-		1,370	S	Dep	OEB	Well		SiL	15	0	0	Out	15	2^E
112	AL1	2	2	0	-	-	-		1,390		Up	OEB	Well		SiL	5	0	0	Out	2	1
113	BT1	6	1	0	-	-	-		1,390	S	Mid	OEB	M. Well		FSL	10	0	0	Un	6	1
114	BK1	5	1	1	-	-	-	G_h^F	1,395	SE	Mid	OEB	Rapid		L	15	0	0	Out	5	1
115	BK1	15	1	0	-	-	-	G_h^F	1,400	E	Low	OEB	Well		SiL	5	5	0	Out	7	1
116	BK1	15	1	0	-	-	-		1,400	SE	Low	OEB	Rapid		SL	10	8	0	Out	5	1
117	BK1	12	2	0	-	-	-	G_h^F	1,410	SE	Low	OEB	Well		GL	30	10	0	Out	10	1
118	BK1	2	2	0	-	-	-	Mh	1,410			OEB	Well		SiL	5	5	0	Till	2	1
119	BK1	15	2	0	-	+	-	Mi	1,420	SE	Mid	RG	V. Poor	10	O	0	0	0	Till	5	3^M
120	BK1	3	2	0	-	-	-	Mh	1,420			GOEB	M. Well		SiL	5	5	0	Till	3	1
121	BK1	13	3	0	-	-	-	Mr	1,435	W	Mid	OEB	M. Well		SiL	10	10	0	Till	10	2^S
122	BK1	2	1	1	-	-	-	Mr	1,435	W	Cres	OEB	Well		SiL	5	5	0	Till	2	1
123	BK1	5	1	0	-	-	-	Mr	1,435	W	Up	OEB	Well		SiL	5	5	0	Till	2	1

Site												Soil										
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
124	BK1	12	2	0	–	–	–	Mr	1,450	W	Mid	OEB	Well		SiL	5	5	0	Till	8	2^S
125	BK1	6	1	0	–	+	–	Mr	1,450	E	Mid	OEB	M. Well		SiL	5	5	0	Till	2	2^M
126	BK1	5	2	0	–	+	–	Mr	1,465	SE	Mid	GOEB	Imp	30	SiL	5	5	0	Till	3	2^M
127	BK1	7	2	0	–	+	–	Mr	1,465	SE	Mid	OEB	M. Well		SiL	5	5	0	Till	7	2^M
128	BK1	9	1	0	–	+	–	Mr	1,465	S	Mid	GOEB	Imp	50	SiL	10	0	0	Till	9	2^E_M
129	BK1	8	2	0	–	–	–	Mr	1,475	SW	Cres	OEB	Well		SiL	5	5	0	Till	6	2^S
130	BK1	4	2	0	–	–	–	Mr	1,475	SW	Cres	BGL	Well		GCL	15	10	0	Till	4	1
131	BK1	8	2	0	–	–	–	Mr	1,490	S	Cres	BGL	Well		SiL	5	0	0	Till	8	1
132	BK1	3	2	0	–	–	–	Mr	1,495			BGL	M. Well		SiL	5	5	0	Till	3	1
133	BK1	10	2	0	–	+	–	Mr	1,495	SW		BGL	M. Well		SiL	5	5	0	Till	10	2^M_S
134	BK1	3	2	0	–	–	–	Mr	1,500			BGL	Well		CL	15	0	0	Till	2	1
135	BK1	2	2	0	–	–	–	Mr	1,505		Cres	BGL	Well		SiL	0	0	0	Till	2	1
136	BK1	10	1	0	–	+	–	Mr	1,495	E	Low	GOEB	Imp	15	SiL	5	0	0	Till	6	3^M
137	BK1	2	1	0	–	+	–	Mr	1,495		Dep	GDEB	Imp	15	SiL	5	5	0	Till	2	3^M_R
138	BK1	5	2	0	–	+	–	Mr	1,505	S	Low	GBGL	Imp	40	SiL	5	5	0	Till	5	2^M_R
139	BK1	8	2	0	–	–	–	Mr	1,510	S	Mid	BGL	M. Well		SiL	5	5	0	Till	8	1
140	BK1	10	2	0	–	–	–	Mr	1,510	SW	Mid	BGL	Well		SiL	5	0	0	Till	10	2^M
141	BK1	5	2	0	–	–	–	Mr	1,525	SW	Cres	BGL	Well		SiL	5	5	0	Till	3	1
142	BK1	8	1	0	–	–	–	Mr	1,495	N	Mid	BGL	M. Well		SiL	5	5	0	Till	2	2^M_W
143	BK1	2	0	0	–	+	–	Mr	1,525			O	V. Poor	0	O	0	0	0	Till	2	5^M
144	BK1	8	1	0	–	–	–	Mr	1,525	S	Mid	GOEB	Imp	30	SiL	5	0	0	Till	2	2^M
145	BK1	2	3	0	–	–	–		1,450		Toe	OEB	M. Well		GSiL	10	15	0	Till	2	2^S
146	BK1	60	2	0	–	–	–	Mr	1,450		Toe	BGL	M. Well		SiCL	10	5	0	Till	2	2^M_R
147	BK1	45	2	0	–	–	–	Mr	1,465	N	Low	BGL	Well		SiCL	10	5	0	Till	15	3^R
148	BK1	38	2	0	–	–	–	Mr	1,480	NE	Mid	BGL	Well		SiL	5	5	0	Till	18	3^E

Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
		Site										Soil									
149	BK1	25	2	0	–	–	–	Mr	1,480	N	Mid	OEB	Well		SiL	5	5	0	Till	18	2^{E}
150	BK1	5	2	0	–	+	0	Mr	1,515	E	Dep	OG	Poor	35	CL	10	5	0	Till	5	2^{M}_{W}
151	BK1	17	2	0	–	–	–	Mi	1,570			OEB	Well		L	10	5	0	Till	17	2^{E}_{R}
152	TA1	2	2	0	–	–	–	G_1^F	1,420			GOEB	Imp		SiL	10	10	0	Out	2	2^{W}_{M}
153	TA1	2	2	0	–	–	–	G_1^F	1,420			GOEB	Imp		SiL	5	5	0	Out	2	2^{W}_{M}
154	TA1	2	2	0	–	–	–	G_1^F	1,420			GOEB	Imp		SiL	5	5	0	Out	2	2^{W}_{M}
155	TA1	2	2	0	–	–	–	G_1^F	1,420			GOEB	Imp		SiL	5	10	0	Out	2	2^{W}_{M}
156	PL4	40	2	0	–	–	–	Mb	2,240	SW	Mid	OMB	Well		SiL	5	0	0	Till	10	1
157	R + MP3	30	2	0	–	–	–	Mb	2,300	W	Mid	OMB	Well		SiL	5	0	0	Till	8	1
158	R + MP3	40	1	0	–	–	–	Mb	2,315	SW	Mid	OMB	Well		SiL	5	0	0	Till	10	1
159	R + MP3	40	1	2	–	–	–	Mb	2,325	SW	Low	OMB	Well		SiL	5	0	0	Till	10	1
160	PL4	25	1	0	–	–	–	Mb	2,275	SW	Mid	OMB	Well		SiL	5	0	0	Till	10	1
161	PL4	40	2	0	–	–	–	Mb	2,200	SW	Mid	OMB	Well		GL	25	0	0	Till	30	3^{E}
162	PL1	45	3	2	–	–	–	Mv	2,170	SW	Mid	OEB	Well		SiL	5	5	0	Till	8	1
163	PL1	20	2	0	–	–	–	Mv	2,145	S	Mid	OEB	Well		SiL	5	0	0	Till	20	2^{E}
164	PL1	15	1	2	–	–	–	Mv	2,135	S	Dep	OEB	M. Well		SiL	15	0	0	Till	15	2^{E}
165	PL1	5	1	2	–	+	–		2,120		Dep	GMB	Imp		SiL	0	0	0	All	5	3^{M}
166	64 + 57	12	2	0	–	–	–	Mb	1,550	N	Low	OEB	Well		GSiL	40	5	0	Till	6	1
167	64 + 57	25	3	0	–	–	–	Mv	1,560	NE	Mid	OEB	Well		VGSiL	50	15	0	Till	12	2^{E}
168	64 + 57	15	1	0	–	–	–	Mb	1,570	NE	Mid	OEB	M. Well		VGSiL	70	0	0	Till	2	1
169	64 + 57	18	1	0	–	–	–	Mb	1,575	SW	Mid	OEB	Well		VGSiL	80	0	0	Till	2	1
170	64 + 57	25	1	0	–	–	–	Mb	1,575	S	Mid	OEB	Well		VGSiL	80	0	0	Till	4	1
171	64 + 57	20	1	0	–	–	–	Mb	1,580	E		OEB	Well		GSiL	40	0	0	Till	2	1
172		50	2	0	–	–	–		1,575	SE	Mid	OEB	Well		VGL	80	0	0	Col	2	1
173	57	25	2	0	–	–	–	Ci	1,580	SE	Low	OMB	Rapid		SiL	10	0	0	Col	5	2^{D}

Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
	Site											Soil									
174	57	5	1	0	-	-	-	Mb	1,570	SE	Low	OGL	Well		SiL	10	0	0	Loes	5	1
175	57	5	1	0	-	-	-	Mb	1,580	S	Low	DEB	Well		SiL	15	0	0	Till	2	2^W
176	57	13	1	0	-	-	-	Mb	1,575	SE	Low	OEB	M. Well		GSiCL	50	0	0	Till	5	2^W
177		10	1	0	-	-	-	Ff	1,580	SE		OEB	Well		GL	45	0	0	All	3	1
178	38	22	1	0	-	-	-	Ff	1,580	S	Low	OEB	Rapid		VGSiL				All	2	1
179	38	25	1	0	-	-	-	Ff	1,585	S	Low	OEB	Rapid		VGSiL	90	0	0	All	3	1
180	38	30	1	0	-	-	-	Ff	1,585	SE	Low	DBC	Rapid		G	95	0	0	All	5	1
181	64	20	1	0	-	-	-	Mb	1,590	SE	Low	OEB	Rapid		GL	35	5	0	Till	2	1
182	64	10	1	0	-	-	-	Mb	1,590	SE	Low	OMB	Well		GL	35	0	0	Till	2	1
183	64	60	1	0	-	-	-	Mb	1,595	SE	Low	OMB	Well		GL	40	0	0	Till	3	1
184	64	28	2	0	-	-	-	Mb	1,595	SE	Low	DEB	Well		VGL	60	0	0	Till	2	1
185	38	50	2	0	-	-	-	Ff	1,595	SE	Low	OMB	Rapid		VGL	50	10	10	All	3	1
186	141	28	2	0	-	-	-	Ci	1,600	SE	Low	OMB	Rapid		GSiL	30	10	5	Col	4	1
187	28	15	2	0	-	-	-	Ff	1,600	E	Low	OR	Rapid		G	80	10	0	All	2	1
188	38	5	2	0	-	-	-	Ff	1,600	S	Toe	OR	Well		G	80	10	0	All	2	1
189	38	5	2	0	-	-	-	Ff	1,605	SE	Toe	OR	Rapid		GSL				All	2	1
190	20	2	2	0	+	-	-	Fl	1,605			OR	Well		SL	15	0	0	All	2	1
191	20	2	2	0	+	-	-	Fl	1,605			OR	Well		SL				All	2	1
192	20	2	1	0	+	-	-	Fl	1,610			GOEB	Imp		FSL				All	2	1
193	142	40	2	0	-	-	-	Cf	1,635	S	Low		Rapid		VGSiL	70	0	0	Col	5	1
194	38	30	3	0	-	-	+	Cf	1,650	SE	Mid	CR	Rapid		GL	30	10	5	Col	3	1
195	38	26	3	0	-	-	+	Ff	1,650	S	Mid	CR	Rapid		VGL	60	15	10	All	8	2
196	141	15	2	0	-	-	-	Mb	1,640	SE	Low	BGL	Well		SiL	5	0	0	Till	15	1
197	28	12	2	0	-	-	-		1,640	S	Low	OEB	Well		SiL	10	0	0	Un	2	1
198	28	6	1	0	-	-	-	Mb	1,645	SE	Low	OEB	Well		SiL	10	0	0	Till	6	1

Site												Soil										
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
199	18	5	1	0	-	-	-	Ft	1,670			OEB	Well		L	10	0	0	All	5	1
200	18	2	2	0	-	-	-	Ft	1,660			OEB	Well		GLS	45	0	0	All	2	1
201	47	15	2	0	-	-	-	Ff	1,675	E	Mid	OEB	Well		GSiL	45	0	0	All	12	1
202	47	15	2	0	-	-	-	Mb	1,685	SE	Mid	OEB	Well		GSiL	45	0	0	Till	14	2^E
203	141 + 156	35	2	1	-	-	-	Cv	1,700	S	Mid	LOEB	Rapid		GSL				Col	15	2^D
204	141 + 156	30	3	0	-	-	-	Mv	1,725	SE	Mid	DEB	Well		GL	30	10	5	Till	15	1
205	38	18	1	0	-	-	+	Ff	1,735	S	Mid	OMB	Well		VGSL	90	0	0	All	11	3^E
206	38	40	2	0	-	-	+	Ff	1,750	S	Mid	OMB	Rapid		VGSiL	90	0	0	All	20	3^E
207	142 + R	35	2	1	-	-	+	Cs	1,750	S	Mid	OMB	Rapid		VGSL	80	5	0	Col	13	2^D
208	141 + R	35	2	2	-	-	+	Cv	1,765	SW	Mid	LR	Well		GSL	40	0	0	Col	20	3^E
209	141 + R	55	0	2	-	-	+	Cv	1,770	SE	Mid	OMB	Well		VGSL	60	10	0	Col	18	2^D
210	141 + R	50	1	2	-	-	+	Cv	1,780	SE	Mid	OMB	Rapid		VGSL	80	0	0	Col	18	2^E_D
211	147	38	2	0	-	-	-	Ff	1,670	S	Low	OEB	Well		VGSL	80	0	0	All	14	2^E
212	141	50	2	0	-	-	-	Cv	1,675	S	Low	OEB	Well		VGSL	80	5	0	Col	20	2^E
213	141	30	2	0	-	-	-	Mb	1,690	SE	Mid	OEB	Rapid		GSL	40	5	0	Till	10	1
214	90R	30	1	0	-	-	-	Mv	1,700	S	Mid	OEB	Well		VGSL	80	0	0	Till	10	1
215	90R	30	1	2	-	-	-	Mv	1,705	S	Mid	OEB	Well		VGSL	80	0	0	Till	10	2^E
216	90R	35	1	0	-	-	-	Cv	1,725	S	Mid	OEB	Rapid		G	95	0	0	Col	12	2^E
217	141	28	2	1	-	-	-	Cv	1,730	SE	Mid	OEB	Well		GL	40	10	0	Col	15	2^E
218	141	33	2	0	-	-	-	Mb	1,740	S	Mid	OEB	Well		GSL	35	10	0	Till	11	2^E
219	141	27	2	0	-	-	-	Mb	1,750	S	Mid	BGL	Well		GL	30	5	0	Till	15	2^E
220	141	50	1	0	-	-	-	Cv	1,755	S	Mid	OEB	Rapid		G	95	0	0	Col	7	1
221	90R	60	2	1	-	-	-	Cb	1,755	S	Mid	OMB	Rapid		VGSL	70	0	0	Col	2	1
222	90R	45	2	3	-	-	-	Cv	1,760	S	Mid	LOEB	Well		GSL	40	0	0	Col	16	2^E
223	156	15	2	0	-	-	-	Mv	1,760	S	Mid	OEB	Well		GSiL	30	10	0	Till	15	2^E

Site												Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
224	156	27	2	0	-	-	-	Mv	1,780	S	Mid	OEB	Well		GSiL	20	5	0	Till	18	2^E
225	156	20	2	0	-	-	-	Mb	1,795	SE	Mid	OEB	Well		SiL	15	0	0	Till	15	2^E
226	156	50	2	0	-	-	-	Mb	1,800	S	Mid	OEB	Well		GSiL	35	0	0	Till	2	1
227	156	35	2	0	-	-	-	Mb	1,800	S	Mid	BGL	Well		GL	30	5	0	Till	20	1
228	156	25	2	0	-	-	-	Mb	1,810	S	Mid	OEB	Well		GSiL	35	10	0	Till	12	1
229	156	45	2	0	-	-	-	Mb	1,815	S	Mid	OEB	Well		GSiL	40	5	0	Till	7	1
230	156	35	2	0	-	-	-	Mb	1,820	S	Mid	OEB	Well		GSiL	35	5	0	Till	5	1
231	Chute	45	2	0	-	-	+	Mv	1,825	S	Mid	OMB	Well		GSiL	30	10	0	Till	7	2^E
232	Chute	40	2	0	-	-	+	Mv	1,830	S	Mid	OMB	Well		VGSiL	60	10	0	Till	5	1
233	48	10	1	0	-	-	-	Ff	1,450	NE	Mid	OMB	Well		VGSiL	70	5	0	All	8	2^D
234	48	10	1	0	-	-	-	Ff	1,455	NE	Mid	OMB	Well		VGSiL	60	5	0	All	8	2^D
235	48	15	2	0	-	-	-	Pf	1,455	N	Mid	OMB	M. Well		GSiL	40	5	0	All	8	2^C
236	48	12	2	0	-	-	-	Ff	1,460	E	Mid	OEB	Well		GSiL	20	10	0	All	12	3^E
237	48	30	2	0	-	-	-	Mb	1,465	E	Mid	OEB	Well		SiL	5	0	0	Till	10	2^E
238	48	35	2	1	-	-	-		1,495	NE	Mid	DEB	Well		SiL	10	0	0	Un	15	1
239	28 + 27	22	2	0	-	-	-	Mb	1,500	NE	Mid	OEB	Well		SiL	5	0	0	Till	8	1
240	28 + 27	20	2	2	-	-	-	Mv	1,500	NE	Mid	OEB	Well		SiL	5	5	0	Till	10	2^D
241	90R	28	2	4	-	-	-	Uv	1,505	E	Mid	OEB	Well		SiL	10	0	0	Un	15	3^E_D
242	90R	15	2	4	-	-	-	Uv	1,525	NE	Mid	LOEB	Well		SL	10	5	0	Un	15	2^C
243	27 + 28	20	2	0	-	-	-	Fb	1,535	NE	Mid	OEB	Well		SL	10	5	0	All	8	1
244	27 + 28	7	1	0	-	-	-	Ff	1,545	NE	Up	OMB	M. Well		GSiL	40	0	0	All	7	1
245	27 + 28	12	1	0	-	-	-	Ff	1,545	NE	Up	OEB	Well		SiL	15	0	0	All	12	2^D
246	27 + 28	10	2	1	-	-	-	Ff	1,550	N	Dep	OEB	Well		VGSL	80	0	0	All	10	2^E
247	27 + 28	17	2	5	-	-	-	Uv	1,565	E	Dep								Un	17	3^E_C
248	MP2	12	1	0	-	+	-	Mb	2,310	S	Low	GMB	Imp		SiL	20	0	0	Till	12	3^M_E

Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
		Site										Soil									
249	MP2	12	1	1	-	+	-	Mb	2,315	S	Low	GTSHFP	Imp	35	SiL	15	0	0	Till	12	3^{M}_{E}
250	MP2	10	1	0	-	+	-	Mb	2,315	S	Mid	GTMB	Imp	30	SiL	15	0	0	Till	10	4^{M}_{E}
251	MP2	7	1	0	-	+	-	Mb	2,325	S	Mid	GTSHFP	Imp	30	SiL	5	0	0	Till	7	4^{M}
252	MP2	6	1	0	-	+	-	Mb	2,330	S	Up	GTSHFP	Imp	18	SiL	10	0	0	Till	6	3^{M}
253	MP2	5	1	0	-	+	-	Mb	2,330	S	Up	GTSHFP	Imp	20	SiL	10	0	0	Till	5	3^{M}_{E}
254	WR1	4	2	0	+	-	-	Ff	1,310	S	Low	OR	M. Well		VGSL	75	10	0	All	4	2^{D}
255	WR1	4	2	0	+	-	-	Ff	1,310	S	Mid	OR	M. Well		VGSL	75	10	0	All	4	2^{D}
256	WR1	4	3	0	+	-	-	Ff	1,320	S	Mid	OR	M. Well		VGLS	80	10	0	All	4	2^{D}
257	WR1	3	3	0	-	-	-	Ff	1,325	S	Mid	OR	M. Well		VGSL	70	15	0	All	3	2^{D}
258	WR1	3	2	0	-	-	-	Ff	1,325	S	Mid	OR	M. Well		VGLS	80	10	0	All	3	2^{D}
259	OL2	35	2	0	-	-	-	Mb	1,340	E	Low	OEB	Well		SiL	5	5	0	Till	15	3^{S}_{E}
260	OL2	30	2	0	-	-	-	Mb	1,360	SE	Low	OEB	Well		SiL	10	5	0	Till	15	2^{E}_{D}
261	OL1	15	2	0	-	-	-	Mb	1,440	NE	Mid	DEB	Well		SiL	5	0	0	Till	3	2^{W}
262	OL1	20	1	0	-	-	-	Mb	1,445	SE	Mid	DEB	Well		SiL	5	0	0	Till	5	2^{W}_{D}
263	OL1	20	1	0	-	-	-	Mb	1,435	SE	Mid	DEB	Well		SiL	5	0	0	Till	10	2^{D}
264	CM1	10	2	0	-	-	-		1,705	E	Low	OEB	Well		FSL	5	0	0	Till	3	1
265	CM1	10	2	0	-	-	-		1,710	E	Low	OEB	M. Well		SiL	10	0	0	Till	2	1
266	CM1	20	2	0	-	-	-	Mb	1,720	E	Low	DDB	Well		GSiL	30	0	0	Till	10	2^{S}
267	CM1	18	3	0	-	-	-	Mb	1,725	E	Low	ODB	Well		VGSiL	50	10	10	Till	10	2^{S}
268	CM1	40	3	0	-	-	-	Mb	1,730	E	Low	DDB	Well		FSL	10	5	5	Till	20	2^{S}
269	CM1	20	1	0	-	-	-	Mb	1,735	E	Low	DDB	Well		GSiL	30	0	0	Till	2	1
270	BG4A	35	3	0	-	-	+	Mb	1,745	E	Mid	OEB	Well		SiL	5	10	5	Till	20	2^{E}_{S}
271	BG4A	35	2	0	-	-	+	Cb	1,750	E	Mid	OR	Well		SiL	5	5	0	Col	12	2^{M}
272	BG4A	35	3	0	-	-	+	Cb	1,760	E	Mid	OR	Well		GSiL	15	10	5	Col	3	2^{S}
273	BG4A	55	2	0	-	-	+	Mb	1,770	E	Mid	OHFP	Well		GSL	30	5	5	Till	10	1

Site												Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
274	CM1	45	3	0	-	-	-	Mb	1,775	E	Mid	DDB	Well		GFSL	25	5	5	Till	3	1
275	CM1	40	2	0	-	-	-	Mb	1,775	NE	Mid	DDB	Well		GL	20	5	0	Till	3	1
276	CM1	50	2	0	-	-	-	Mb	1,775	E	Mid	DDB	Well		SL	10	5	5	Till	5	1
277	CM1	45	2	0	-	-	-	Mb	1,775	SE	Mid	ODB	Well		GSL	30	5	0	Till	2	1
278	CM1	50	2	0	-	-	-	Mb	1,775	E	Mid	ODB	Well		SL	15	5	0	Till	3	1
279	CM1	35	2	0	-	-	-	Mb	1,775	E	Mid	ODB	Well		GL	30	5	0	Till	2	1
280	CM1	55	2	0	-	-	-	Mb	1,775	E	Mid	DDB	Well		FSL	15	5	0	Till	3	1
231	CM1	50	2	0	-	-	-	Mb	1,775	E	Mid	DDB	Well		SL	15	5	0	Till	2	1
282	WR1	35	2	0	-	-	-	Ff	1,775	E	Mid	ODB	Well		FSL	10	0	0	All	4	1
283	CM1	30	2	0	-	-	-	Mb	1,775	NE	Mid	DDB	Well		GSL	40	5	0	Till	2	1
284	BK3	7	2	0	-	-	-		1,720	NE	Mid	DEB	Well		SL	15	5	0	Un	3	1
285	BK3	10	2	0	-	-	-		1,725	N	Mid	DEB	Well		GSiL	30	0	0	Un	10	2^E
286	BK3	5	2	0	-	-	-		1,725	N	Mid	OEB	Well		SiL				Un	5	1
287	BK3	15	2	0	-	-	-	Mb	1,725	N	Mid	OHFP	Well		FSL				Till	3	1
288	BK3	10	3	0	-	-	-	Mb	1,730	N	Mid	OEB	Rapid		GSiL	10	10	15	Till	10	2^S
289	BK3	10	2	0	-	-	-	Mb	1,735	N	Mid	DEB	Rapid		GSL	30	10	5	Till	10	1
290	BK3	22	2	0	-	-	-	Mb	1,745	N	Mid	DEB	Well		GL	30	10	5	Till	22	1
291	BK3	2	2	0	-	-	-	Mb	1,745			OEB	Well		SiL	10	0	0	Till	2	1
292	PR2	5	2	0	-	-	-	Mb	1,750	N	Mid	DEB	Well		GL	25	10	5	Till	5	1
293	PR2	25	2	0	-	-	-	Mb	1,765	N	Low	DEB	Well		GSL				Till	25	2^E
294	PR2	35	2	0	-	-	-	Mb	1,770	NE	Mid	DEB	Well		FSL	10	5	0	Till	15	2^{E}_{R}
295	PR2	30	2	0	-	-	-	Mb	1,780	NE	Mid	DEB	Well		FSL	15	5	0	Till	15	2^E
296	ML1	15	2	0	-	-	-	Mb	1,805	SE	Mid	OEB	Well		SiL	10	0	0	Till	10	2^M
297	ML1	18	2	0	-	-	-	Mb	1,810	S	Mid	OEB	Well		SL	15	5	0	Till	8	1
298	ML1	15	2	0	-	-	-	Mb	1,825	E	Mid	DEB	Well		LS	15	5	0	Till	11	1

Site												Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
299	ML1	45	2	0	-	-	-	Mb	1,825	S	Mid	OEB	Well		GSL	30	5	0	Till	9	1
300	ML1	55	2	0	-	-	-	Mb	1,825			DEB	Well		GSL	35	10	5	Till	5	1
301	ML1	50	2	0	-	-	-	Mb	1,815	S	Low	DEB	Well		GSL	35	10	0	Till	3	1
302	ML1	50	2	0	-	-	-	Mb	1,825	S	Low	OEB	Well		GLS	40	5	0	Till	3	1
303	ML1	50	2	0	-	-	-	Mb	1,820	S	Low	DEB	Well		L	15	5	0	Till	4	1
304	ML1	40	2	0	-	-	-	Mb	1,815	S	Low	OEB	Well		SL	15	5	0	Till	5	1
305	ML1	45	2	0	-	-	-	Mb	1,815	SE	Low	OEB	Well		SL	15	5	0	Till	2	1
306	ML1	30	2	0	-	+	-	Mb	1,810	SE	Low	GOEB	Imp		SiL	15	5	0	Till	2	2^{W}
307	ML1	25	2	0	-	+	-	Mb	1,820	S	Low	GOEB	Imp		GSiL	40	5	0	Till	3	2^{M}
308	ML1	40	2	0	-	-	-	Mb	1,815	SE	Low	OEB	Well		L	15	5	0	Till	5	1
309	ML1	45	2	0	-	+	-	Mb	1,820	S	Low	OEB	Well		GSL	30	10	0	Till	10	1
310	ML1	40	2	0	-	+	-	Mb	1,810	SE	Low	OEB	Well		GSL	30	10	0	Till	10	1
311	SC	1	0	0	+	-	-	Fl	1,525			GR	Imp		VGSL	80	0	0	All	1	1
312	SC	1	0	0	+	-	-	Fl	1,525			GR	Imp		VGSL	80	0	0	All	1	1
313	SC	1	0	0	+	-	-	Fl	1,525			GR	Imp		GSiL	30	0	0	All	1	1
314	KI2	1	0	0	+	-	-	Fl	1,525			GR	Poor		SiL	0	0	0	All	1	2^{W}
315	KI2	1	0	0	+	-	-	Fl	1,525			GR	Poor		SiL	0	0	0	All	1	2^{W}
316	KI2	1	0	0	+	-	-	Fl	1,525			RG	Poor	20	SiL	0	0	0	All	1	3^{M}
317	KI2	1	0	0	+	-	-	Fl	1,525			RG	Poor	35	SiL	0	0	0	All	1	2^{M}
318	KI2	1	0	0	+	-	-	Fl	1,525			GR	Imp		SiL	0	0	0	All	1	2^{M}
319	KI2	1	0	0	+	-	-	Fl	1,525			GR	Imp		SL	0	0	0	All	1	1
320	SC	1	0	0	+	-	-	Fl	1,525			OR	M. Well		VGSL	80	0	0	All	1	1
321	SC	1	0	0	+	-	-	Fl	1,525			OR	M. Well		VGSL	80	0	0	All	1	1
322	SC	1	0	0	+	-	-	Fl	1,525			OR	M. Well		VGSL	80	0	0	All	1	1
323	KI2	2	1	0	+	-	-	Fl	1,555			GOR	Imp	50	SL	20	0	0	All	2	1

Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
		Site										Soil									
324	KI2	2	1	0	+	-	-	Fl	1,555			GOR	Imp	40	SiL	0	0	0	All	2	2^{W}_{M}
325	KI2	2	0	0	+	-	-	Fl	1,555			GOR	Imp	40	SiL	5	0	0	All	2	2^{M}
326	KI2	2	0	0	+	-	-	Fl	1,555			GOR	Imp	40	SiL	0	0	0	All	2	2^{M}_{W}
327	KI2	2	0	0	+	-	-	Fl	1,555			GOR	Imp	30	SiL	10	0	0	All	2	3^{M}
328	KI2	2	0	0	+	-	-	Fl	1,555			RG	Poor	10	SiL	0	0	0	All	2	5^{F}
329	PL1	15	2	0	-	-	-	Mb	1,840	S	Toe	OEB	M. Well		L	15	5	0	Till	15	3^{M}
330	PL1	28	2	0	-	-	-	Mb	1,860	W	Mid	OEB	Well		SiL	10	0	0	Till	5	2^{M}_{W}
331	PL1	12	2	0	-	-	-	Mb	1,880	W	Up	OEB	Well		SiL	10	5	0	Till	7	3^{M}_{W}
332	PL1	10	1	0	-	-	-	Mb	1,880	SW	Cres	BGL	Well		SiL	5	0	0	Till	5	2^{M}_{W}
333	PL1	3	1	C	-	-	-	Mb	1,885		Cres	DEB	M. Well		SiL	10	0	0	Till	3	3^{M}
334	PL1	2	1	0	-	-	-	Mb	1,890		Cres	BGL	Well		FSL	5	0	0	Till	2	2^{M}_{W}
335	PL1	8	1	0	-	-	-	Mb	1,885	E	Up	OEB	M. Well		SiL	5	0	0	Till	3	2^{M}
336	PL1	25	2	1	-	-	-	Mb	1,885	E	Up	OEB	Well		SiL	5	0	0	Till	4	3^{M}_{W}
337	CM1	45	3	1	-	-	-	Mb	1,605	SE	Low	OEB	Well		VGSL	60	10	5	Till	12	1
338	CM1	55	2	0	-	-	-	Mb	1,605	SE	Low	OEB	Well		SiL	0	0	0	Till	5	2^{E}
339	CM1	40	2	0	-	-	-	Mb	1,615	SE	Low	OEB	Well		SiL	15	0	0	Till	7	2^{E}
340	CM1	20	2	0	-	-	-	Mb	1,620	SW	Toe	OEB	Well		SiL	5	5	0	Till	8	3^{E}_{C}
341	BK1	45	2	0	-	-	-	Mb	1,480	NW	Low	BGL	Well		CL	10	0	0	Till	8	2^{M}
342	BK1	38	2	0	-	-	-	Mb	1,495	E	Up	BGL	Well		CL	15	5	0	Till	30	2^{E}
343	BK1	32	2	0	-	-	-	Mb	1,520	NE	Mid	BGL	Well		GCL	20	5	0	Till	25	1
344	BK1	45	2	0	-	-	-	Mb	1,535	SE	Toe	OEB	Well		SiL	10	0	0	Till	3	1
345	BK1	50	1	0	-	-	-	Mb	1,540	E	Low	OEB	Well		CL	10	5	0	Till	28	1
346	BK1	50	1	0	-	-	-	Mb	1,555	NE	Mid	OEB	M. Well		CL	15	5	0	Till	20	2^{M}
347	BK1	45	2	0	-	-	-	Mb	1,570	SE	Up	OEB	Well		GCL	30	5	0	Till	5	1
348	BK1	25	3	0	-	-	-	Mb	1,605	N	Up	DEB	Well		GL	15	15	10	Till	25	2^{S}

		Site										Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
349	BK1	3	3	0	-	+	-	Mb	1,610		Dep	GOEB	Imp		GSiL	10	10	10	Till	3	3^{E}_{S}
350	BK1	6	2	0	-	-	-	Mb	1,615	NE	Cres	OEB	Well		GSL	40	5	0	Till	6	1
351	BK1	50	2	0	-	-	-	Mb	1,620	SE	Low	OEB	Well		L	15	5	0	Till	8	1
352	BK1	10	3	0	-	+	-	Mb	1,630	N	Dep	OEB	Imp		GL	35	10	0	Till	10	3^{E}_{S}
353	BK1	55	2	0	-	-	-	Mb	1,640	NW	Low	OEB	Well		GSL	40	5	0	Till	30	2^{E}
354	BK1	55	2	0	-	-	-	Mb	1,660	NW	Mid	OEB	Well		VGSL	70	10	5	Till	20	1
355	BK1	35	2	0	-	-	-	Mb	1,675	NW	Mid	DEB	Well		VGL	75	10	5	Till	10	1
356	BK1	5	3	0	-	-	-	Mb	1,675	N	Mid	OEB	Well		GFSL	10	10	10	Till	2	2^{S}
357	BK1	35	2	0	-	-	-	Mb	1,690	N	Mid	OEB	Well		GSL	40	10	0	Till	35	3^{E}
358	BK1	28	2	0	-	-	-	Mb	1,705	N	Mid	OEB	Well		VGSL	60	15	5	Till	28	1
359	BK1	35	3	0	-	-	-	Mb	2,255	S	Mid	ODB	Well		VGSL	60	0	0	Till	3	2^{S}
360	CM1	15	2	0	-	-	-	Mb	1,635	S	Low	OHFP	Well		SiL	5	0	0	Till	8	2^{E}
361	CM1	40	2	0	-	-	-	Mb	1,640	S	Low	OEB	Well		VGSiL	70	10	0	Till	7	2^{E}
362	CM1	35	2	0	-	-	-	Mb	1,645	S	Low	OEB	Well		GL	30	10	0	Till	7	2^{E}
363	CM1	55	2	0	-	-	-	Mb	1,645	S	Mid	OEB	Well		GL	30	10	0	Till	7	1
364	CM1	60	2	0	-	-	-	Mb	1,650	SW	Mid	OEB	Well		GL	20	5	0	Till	7	2^{E}
365	CM1	65	2	0	-	-	-	Mb	1,675	SE	Mid	OEB	Well		L	15	5	0	Till	25	1
366	CM1	50	2	0	-	-	-	Mb	1,685	S	Mid	OEB	Well		CL	15	5	0	Till	22	1
367	CM1	25	2	0	-	-	-	Mb	1,695	W	Up	OGL	Well		L	15	5	0	Till	10	2^{E}
368	CM1	40	2	0	-	-	-	Mb	1,710	SW	Mid	GOEB	M. Well		GSiL	15	10	0	Till	15	2^{E}
369	CM1	55	2	0	-	-	-	Mb	1,725	S	Mid	OHFP	Well		GSiL	40	5	0	Till	10	2^{E}_{M}
370	CM1	35	2	0	-	-	-	Mb	1,740	S	Mid	OEB	Well		GL	25	5	0	Till	7	2^{E}_{M}
371	CM1	2	1	0	-	-	-	Fl	1,740		Dep	GMB	M. Well		SiL	0	0	0	All	2	3^{M}_{W}
372	CM1	2	1	0	-	-	-	Fl	1,745			OEB	Well		SiL	0	0	0	All	2	2^{M}_{W}
373	LV1	5	2	0	-	-	-	Mb	2,225	NE	Up	DEB	Well		FSL	10	0	0	Till	3	

Site												Soil										
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
374	LV1	15	1	0	-	-	-	Mb	2,225		Dep	OHFP	M. Well		SiL	5	0	0	Till	15	1
375	LV1	12	2	0	-	-	-	Mb	2,220	NW	Up	OEB	M. Well		FSL	0	0	0	Till	12	1
376	LV1	20	2	0	-	-	-	Mb	2,260	S	Mid	SHFP	M. Well		GL	20	5	0	Till	3	1
377	LV1	18	3	0	-	-	-	Mb	2,270	S	Low	OEB	Well		GL	20	5	0	Till	3	2^S
378	LV1	25	2	0	-	-	-	Mb	2,270	S	Low	DEB	Well		GSL	25	10	0	Till	5	1
379	LV1	35	2	0	-	-	-	Mb	2,280	S	Low	DEB	Well		GSL	25	10	0	Till	22	2^E
380	LV1	27	2	0	-	-	-	Mb	2,295	S	Mid	DEB	Well		GSiL	25	10	0	Till	22	3^E_C
381	LV1	25	3	0	-	-	-	Mb	2,300	S	Mid	OFHP	Well		SiL	10	0	0	Till	10	3^E_C
332	LV1	20	2	0	-	-	-	Mb	2,325	SE	Mid	OHFP	Well		SiL	10	0	0	Till	14	3^E_C
383	LV1	18	2	0	-	-	-	Mb	2,325	SW	Mid	OEB	Well		SiL	15	0	0	Till	15	2^E
384	LV2	33	2	0	-	-	-	Mb	2,340	SE	Up	OHFP	Well		SiL	10	0	0	Till	20	2^E
385	LV2	20	2	0	-	-	-	Mb	2,355	S	Up	OHFP	Well		SiL	10	0	0	Till	20	2^E
386	LV2	15	2	0	-	-	-	Mb	2,365	SE	Up	OHFP	Well		SiL	0	0	0	Till	5	3^E
387	LV1	45	2	0	-	-	-	Mb	2,215	SE	Mid	OEB	Well		GSL	30	10	0	Till	4	1
388	LV1	40	3	0	-	-	-	Mb	2,220	SE	Mid	OEB	Well		GL	30	10	5	Till	4	2^S
389	LV1	55	2	0	-	-	-	Mb	2,225	SE	Mid	OEB	Well		GSL	30	10	5	Till	5	2^S
390	LV1	40	2	0	-	-	-	Mb	2,225	S	Mid	OEB	Well		GSL	25	5	0	Till	3	1
391	LV1	55	2	0	-	-	-	Mb	2,225	S	Mid	OEB	Rapid		GSL	25	10	0	Till	3	1
392	LV1	65	2	0	-	-	-	Mb	2,225	S	Mid	OEB	Well		GSL	35	10	5	Till	3	1
393	LV1	65	2	0	-	-	-	Mb	2,225	S	Mid	OEB	Well		GSL	20	10	0	Till	3	1
394	LV1	60	2	0	-	-	-	Mb	2,230	SE	Mid	OEB	Well		GSL	30	10	0	Till	3	2^S
395	LV1	35	2	0	-	-	-	Mb	2,230	S	Mid	DEB	Well		GSL	35	10	2	Till	5	1
396	LV1A	33	2	0	-	-	-	Mb	2,230	S	Mid	DEB	Well		GSL	20	5	0	Till	5	1
397	LV1A	40	3	0	-	-	-	Mb	2,230	S	Mid	DEB	Well		GSiL	10	20	0	Till	3	3^S
398	LV1A	30	2	0	-	-	-	Mb	2,230	S	Mid	OEB	Well		VGSL	50	10	5	Till	5	2^S

Site												Soil									
Site No.	Map Unit[1]	Slope %	Stoniness[2]	Rockiness[3]	Flooding	Seepage	Avalanching	Landform[4]	Elevation (m)	Aspect	Position on Slope	Classification[5]	Drainage[6]	W. T.[7] (cm)	Texture[8]	Gravel %	Cobbles %	Stones %	Parent Material	Tread Slope %	Response[9]
399	LV1A	45	3	0	-	-	-	Mb	2,230	S	Mid	DEB	Well		VGSL	70	10	5	Till	7	2^S_R
400	LV1A	45	3	0	-	-	-	Mb	2,230	S	Mid	OEB	Well		GSL	30	10	5	Till	5	3^S
401	SK1	8	2	2	-	-	-	Uv	2,200	N	Up	LSHFP	M. Well		SiL	10	0	0	Un	8	4^M
402	SK1	12	2	2	-	+	-	Uv	2,195	SE	Mid	OHFP			SiL	5	0	0	Un	12	2^M
403	SK1	5	3	2	-	-	-	Uv	2,195	SW	Mid	OEB	M. Well		SiL	10	0	0	Un	5	2^M
404	SK1	8	2	3	-	-	-	Uv	2,200	NW	Mid	LR			SiL	0	0	0	Un	8	2^M
405	SK1	12	2	0	-	-	-	Mv	2,195	SW	Low	DEB	M. Well		SiL	10	0	0	Till	7	2^M
406	SK1	5	1	0	-	-	-	Mv	2,200			OFHP	M. Well		SiL	5	5	0	Till	5	2^M
407	SK1	7	2	0	-	-	-	Mv	2,205	W	Up	OEB	M. Well		SiL	5	0	0	Till	7	2^M
408	SK1	30	2		-	-	-	Cb	2,205	W	Mid	OFHP	Well		SiL	5	0	0	Col	5	2^S
409	002	15	3	0	-	-	-	Mv	2,215	S	Mid	SHFP	Well		VGL	50	15	0	Till	8	2^S
410	002	10	3	0	-	-	-	Mb	2,215	SW	Up	SHFP	Well		SiL	10	10	0	Till	7	3^S_M
411	OH1	10	2	0	-	-	-	Mb	2,020	E	Mid	DDB	Well		SiL	10	0	0	Till	10	2^S
412	OH1	11	2	0	-	-	-	Mb	2,015	NE	Mid	DDB	Well		FSL	10	0	0	Till	11	2^S
413	OH1	14	3	0	-	-	-	Mb	2,010	NE	Mid	DDB	Well		FSL	15	0	0	Till	14	3^S
414	OH1	1	2	0	-	-	-	Mb	2,000	E	Low	DDB	Well		FSL	10	0	0	Till	1	2^S
415	OH1	10	2	0	-	-	-	Mb	1,995	E	Low	DDB	M. Well		SiL	10	10	0	Till	10	2^S_M
416	OH1	30	3	0	-	-	-	Mb	2,005	NW	Low	OHFP	Well		SiL	10	0	0	Till	5	2^S
417	OH1	45	2	0	-	-	-	Mb	2,005	NW	Low	OHFP	Well		SiL	10	0	0	Till	14	2^S
418	OH1	45	3	0	-	-	-	Mb	2,005	NW	Mid	DDB	Well		CSL	40	10	0	Till	18	1
419	OH1	55	3	0	-	-	-	Mb	2,010	NW	Mid	DD3	Well		GSL	30	10	0	Till	25	1
420	OH1	22	3	0	-	-	-	Mb	2,015	NW	Mid	DDB	Well		GL	35	5	0	Till	3	1
421	OH1	25	2	0	-	-	-	Mb	2,010	E	Mid	OHFP	Well		GL	35	10	0	Till	20	1

Footnotes:

1. Refer to Soil Survey of the Yoho National Park, B.C. (Coen, Epp, and Tajek, 1977); Biophysical Land Classification of Banff National Park, Progress Report No. 2, 1975-1976 (Walker, Kojima, Coen, and Holland, 1976); and Soils of Waterton Lakes National Park, Alberta (Coen and Holland, 1976) for map unit descriptions.
2. See Stoniness classes on page 49.
3. See Rockiness classes on page 140 in The System of Soil Classification for Canada (CSSC, 1976).
4. See Landform classification in Appendix C.
5. Soils are classified according to The System of Soil Classification for Canada (1976).
6. See Drainage classes on pages 220-221 in The System of Soil Classification for Canada (CSSC, 1974).
7. Water table depths are recorded only when water table was observed or directly inferred and refers to the depth of water table at the time of observation.
8. See definitions of textural classes in Appendix D.
9. See trail rating system in Appendix E.

APPENDIX C

LANDFORM CLASSIFICATION

The landform classification system used in this study has been adapted from Chapter 17 in The Canadian System of Soil Classification (CSSC, 1976). The landforms are classified in terms of genetic materials and surface expression. One qualifying descriptor (G for glacial) may be used to qualify one of the genetic materials. Definitions and descriptions of the classes are provided below.

Genetic Materials

Materials are classified according to their essential properties within a general framework of their mode of deposition. All of the materials examined in this study belong to the unconsolidated group.

The unconsolidated mineral component is comprised of clastic sediments that may or may not be stratified but, whose particles are not cemented together. They are essentially of glacial or post glacial origin but, also include poorly consolidated and weathered bedrock.

Classes:
- C - Colluvial
- F - Fluvial
- L - Lacustrine
- M - Morainal
- U - Unconsolidated, undifferentiated

Definitions

Colluvial: Massive to moderately well stratified, non-sorted to poorly sorted sediments with any range of particle sizes from clay to boulders and blocks that have reached their present position by direct, gravity-induced movement.

They are restricted to products of mass-wasting whereby the debris is not carried within, on, or under another medium possessing

contrasting properties. The assumed process status is active.

Processes includes slow displacements such as creep and solifluction and rapid movements such as earth flows, rockslides, avalanches, and falls. Where colluvial materials are derived from an unconsolidated deposit, but overlie a different unit or form a discrete surface expression, they will be mapped as colluvial. But colluvial material derived from unconsolidated Quaternary sediments, which overlies and resembles its parent unit, will be mapped as the parent unit. Colluvial materials exclude those materials deposited at the base of steep slopes by unconcentrated surface run-off or sheet erosion.

Fluvial: Sediment generally consisting of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well-sorted and display stratification, although massive, non-sorted fluvial gravels do occur. These materials have been transported and deposited by streams and rivers.

The assumed process status is inactive.

Examples: channel deposits, overbank deposits, terraces, alluvial fans and deltas.

Lacustrine: Sediment generally consisting of either stratified fine sand, silt and clay deposited on the lake bed or moderately well-sorted and stratified sand and coarser materials than are beach and other near-shore sediments transported and deposited by wave action.

These are materials that have either settled from suspension in bodies of standing fresh water or that have accumulated at their

margins through wave action. The assumed process status is inactive.

Examples: lake sediments and beaches.

Morainal: Sediment generally consisting of well-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, often in a mixture of sand, silt and clay that have been transported beneath, beside, on, within and in front of a glacier and not modified by any intermediate agent.

Examples: basal till (ground moraine), lateral and terminal moraines, rubbly moraines of cirque glaciers, hummocky ice-disintegration moraines, and pre-existing, unconsolidated sediments re-worked by a glacier so that their original character is largely or completely destroyed.

Unconsolidated: A layered sequence of more than three types of genetic material outcropping on a steep erosional escarpment.

This complex class is to be used where units relating to individual genetic-materials cannot be delimited separately at the scale of mapping. It may include colluvium derived from the various genetic materials and resting upon the scarp slope.

Surface Expression

The surface expression of genetic materials is their form (assemblage of slopes) and pattern of forms. Form, as applied to unconsolidated deposits refers specifically to the product of the initial mode of origin of the materials. Surface expression also expresses the manner in which unconsolidated genetic materials relate

to the underlying unit.

Classes for unconsolidated and consolidated components:

b - Blanket
f - Fan
h - Hummocky
i - Inclined
l - Level
r - Ridged
t - Terraced
u - Undulating
v - Veneer

Definitions

Blanket: A mantle of unconsolidated materials thick enough to mask minor irregularities in the underlying unit but which still conforms to the general underlying topography.

Examples: lacustrine blanket overlying hummocky moraine.

Fan: A fan-shaped form that can be likened to the segment of a cone, and possessing a perceptible gradient from the apex to the toe.

Examples: Alluvial fans, talus cones.

Hummocky: A very complex sequence of slopes extending from somewhat rounded depressions or kettles of various size to irregular to conical knolls or knobs. There is a general lack of concordance between knolls or depressions. Slopes are generally between 5^{o} and 35^{o}.

Examples: hummocky moraine, hummocky glaciofluvial.

Inclined: A sloping, unidirectional surface with a generally constant slope not broken by marked irregularities. Slopes are between 1^{o} and 35^{o}. The form of inclined slopes is not related to the initial mode of origin of the underlying material.

Examples: terrace scarps, river banks.

Level: A flat or very gently sloping, unidirectional surface with a generally constant slope not broken by marked elevations and depressions. Slopes are generally less than 1^{o}.

Examples: floodplain, lake plain.

Ridged: A long, narrow elevation of the surface, usually sharp crested with steep sides. The ridges may be parallel, sub-parallel or intersecting.

Examples: Eskers, crevasse fillings, some drumlins.

Terraced: Scarp face and the horizontal or gently inclined surface (tread) above it.

Examples: Alluvial terrace.

Undulating: A very regular sequence of gentle slopes that extend from rounded, sometimes confined concavities to broad rounded convexities producing a wave-like pattern of low local relief. Slope length is generally less than 0.5 miles and dominant gradient of slopes from 1^{o} to 2^{o}.

Examples: some drumlins, some ground moraine, lacustrine veneers and blanket over morainal deposits.

Veneer: Unconsolidated materials too thin to mask the minor irregularities of the underlying unit surface. A veneer will range between 10 cm and 1 m in thickness and will possess no form typical of the materials genesis.

Example: shallow lacustrine deposits overlying glacial till.

Qualifying Descriptor

One descriptor is used to qualify the clastic genetic material and to supply additional information about the mode of formation or depositional environment.

Glacial (G): Used to qualify non-glacial genetic materials where there is direct evidence that glacial ice exerted a strong control upon the mode of origin of the materials or mode of operation of the process. The use of this descriptor implies that glacier ice was close to the site of the deposition of a material or the site of operation of a process.

APPENDIX D

MANUAL DETERMINATION OF SOIL TEXTURAL CLASSES

The mineral portion of the soil is divided into three size fractions: the coarsest is called sand (S), the medium is called silt (Si), and the finest is called clay (C). Soil texture refers to the relative percentage of sand, silt and clay in a soil and is expressed by means of class names which are found in the soil textural triangle (Fig. D-1).

Accurate determinations of the percentages of sand, silt and clay may be made using laboratory methods, but when in the field, it is desireable to be able to estimate the soil texture by "feel". To determine the texture manually, follow the steps below:

1. Think of the textural triangle in a modified manner. Basically it can be thought of as consisting of three horizontal rows with the lines at about 25 percent and 40 percent clay content. Textures in the upper row are quite plastic (like plasticene) and can be rolled out to form very thin ribbons. Textures in the middle row are moderately plastic and form medium ribbons and textures in the lower row have little plasticity and form poor or no ribbons.
2. Determine the row where the soil best fits by determining its degree of plasticity and its ability to be rolled into ribbons. To do this, place a small amount (about 1 tablespoon) of soil in the palm of the hand and add water drop by drop. Knead the soil all the while and bring it to the consistency of moist workable putty. Now determine its placticity and see how well it rolls into ribbons.
3. Having determined which row the soil fits into, think of the textural triangle as being broken into three columns with lines at about 20 percent and 50 percent sand content. Textures in the

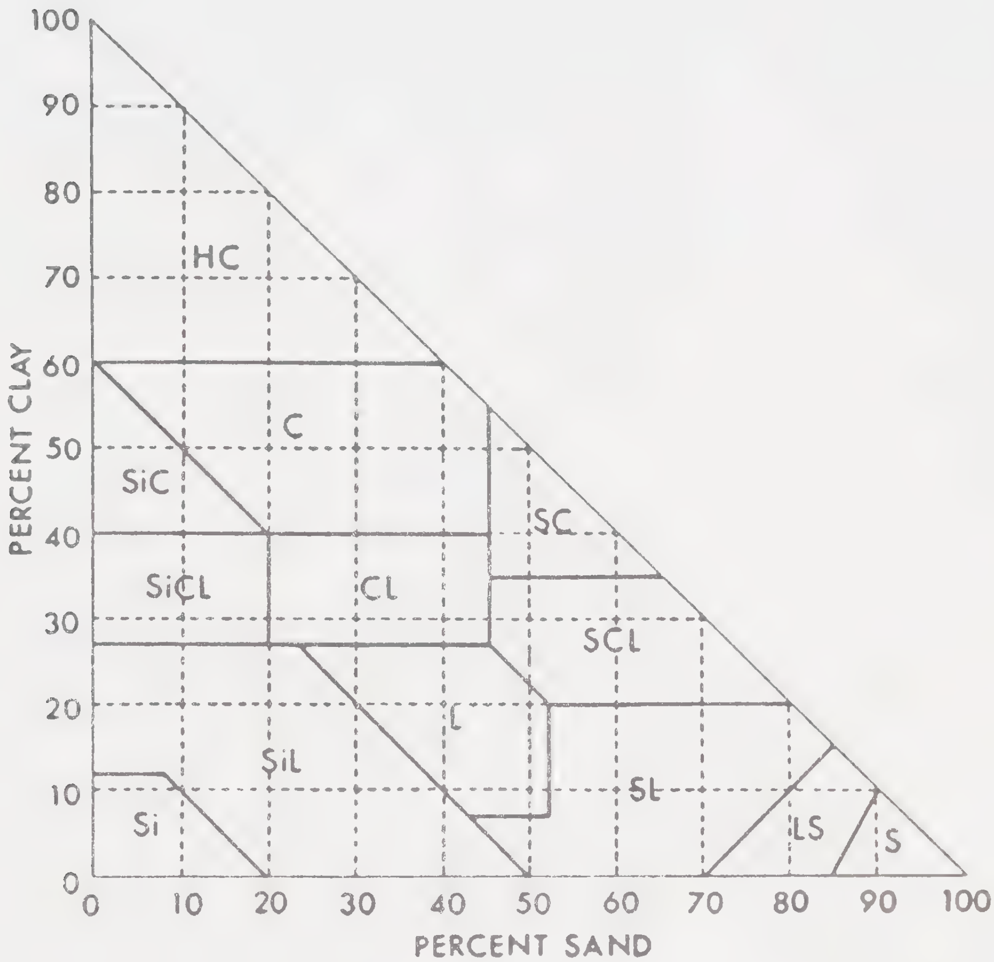

Figure D-1. Soil Textural Triangle (CSSC, 1976).

right hand row will have a definite gritty feel while textures in the left hand row will feel exceptionally smooth with no grittiness.

4. Combining the results of steps 2 and 3 will result in an approximate placement of the soil into a textural class. With practice, this method can be fairly accurate.

APPENDIX E

TRAIL RATING SYSTEM

The trail rating system (Table E-1) was developed as the mechanism to measure or evaluate the effects of soil ans site parameters on trail response. The rating system used in this study is similar to that of Trottier and Scotter (1973, 1975) but differs in several important aspects related to the objectives of this study. The parameters of moisture regime and stones and roots on the tread have been subdivided so as to provide more specific information about the nature of the impairments. Walkability is not rated separately since it is already accounted for in the other ratings. Thus, the parameters considered in this study are width, depth (area lost), muddiness, dustiness, loose coarse fragments on trail tread, coarse fragments embedded in the trail tread, and roots in the trail tread. Definitions of the qualitative items are given below. Five degrees of trail response are used with class 1 being good and class 5 being rated as unuseable.

An overall condition or response rating is assigned to each site on the basis of the severest rating of the individual parameters. Exceptions to this are (1) roots which were not removed during construction, rather than as a result of wear or erosion, are omitted from the overall rating because they do not indicate a soil problem; and (2) a severe rating is occasionally assigned when a combination of parameters result in the walkability of the trail being significantly worse because of the combination than the individual responses would indicate.

The individual responses are not added to give the overall rating as was done by Trottier and Scotter (1973, 1975), because it is felt that this could imply differences or similarities which do not exist when using the parameters which have been used in this study.

Table E-1. Trail Rating Scheme

Parameters	Response: 1 Good	2 Medium	3 Poor	4 V. Poor	5 Unuseable
Width	<50 cm	50-100 cm	100-200 cm	200-300 cm	>300 cm
Depth	<5 cm	5-20 cm	20-50 cm	50-150 cm	>150 cm
Area	<250 cm^2	250-2,000 cm^2	2,000-10,000 cm^2	10,000-30,000 cm^2	>30,000 cm^2
Muddiness	Dry	Soft	Muddy	V. muddy	Bog, flooded
Dustiness	Non-dusty	Slightly dusty <5 mm	*	*	*
Loose C.F.	Stable footing	Slightly unstable footing	Mod. unstable footing	Very unstable footing	*
Embedded C.F.	None (<5%)	Few, mostly avoidable (5-20%)	Many, some unavoidable (20-50%)	V. many, unavoidable (>50%)	*
Roots	None	Few, avoidable	Many, some unavoidable	V. many, unavoidable	*

* Indicates ratings not established because conditions of this severity were not encountered during study.

For example, using Trottier and Scotter's rating system, a trail might be unuseable because of muddiness, but a low (good) overall rating could result if the other parameters received a low rating. Conversely, another trail with medium or poor ratings for several parameters could receive a

higher (worse) overall rating even though that trail is more useable.

Definitions of the qualitative terms used in Table E-1 are as follows:

<u>Muddiness</u>

1. Dry - the walking surface is in a dry state. No imprints due to hiking boots or horses hooves visible.
2. Soft - the walking surface is in a soft, moist state. "Vibram" soled hiking boots leave imprints and footing may be slippery on grades.
3. Muddy - the walking surface is being churned up by traffic causing unpleasant walking conditions. Muddy footwear and muddy pantlegs are common when hiking on a trail in this condition, but hikers will still use the trail rather than detouring.
4. Very muddy - the walking surface has been churned into a quagmire or excessive water is ponded on trail. Most people will detour if possible.
5. Bog, flooded - the walking surface has mud deeper than the tops of hiking boots or is flooded. Detour is necessary.

<u>Dustiness</u>

1. Non-dusty - no dust is visible on trail and no dust accumulates on footwear.
2. Slightly dusty - up to 5 mm dust present on trail. Dusty footwear results from this but dust does not rise much above the trail when disturbed.

Loose Coarse Fragments

1. Stable - no footing problems due to loose coarse fragments. Percentage of loose coarse fragments present varies with size and trail grade.
2. Slightly unstable footing - occasional traction problems on grades.
3. Moderately unstable footing - traction problems on grades or slight chance of twisting ankle.
4. Very unstable footing - difficult to get up grades or moderate chance of twisting ankle.

Embedded Coarse Fragments and Roots

1. None - embedded coarse fragments or roots are far enough apart so as to provide no impediment to travel. Percentages of c.f. vary with size.
2. Few, avoidable - embedded coarse fragments and roots can be avoided but some attention must be paid to trail when walking. Percentages of c.f. vary with size.
3. Many, some unavoidable - toes will be stubbed often if attention is not on trail. Percentages of c.f. vary with size.
4. Very many, unavoidable - speed of travel is reduced due to continual stepping off trail to avoid stones or roots. Percentages of c.f. vary with size.

The guidelines for rating trail condition are rather arbitrary, and while they were generally followed in this study, one noteable exception did occur. Trails which were constructed wider than 50 cm still received a width rating of 1 rather than a rating in accordance with Table E-1.

APPENDIX F

Calculations of Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Selected Observations

Appendix F-1. Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Gravel Contents

Sites Used for Comparison of Gravel Contents

0-20%	72, 73, 105, 190, 191, 276, 278, 281, 284, 297, 305
20-50%	75, 218, 277, 283, 299, 300, 301, 304, 309, 310
> 50%	205, 211, 214, 254, 255, 320, 321, 322

Gravel Content Results

Gravel Contents		0-20%	20-50%	>50%	Combination
Observations (Responses)	1	11	9	4	
	2	-	1	3	
	3	-	-	1	
	4	-	-	-	
	5	-	-	-	
	T	11	11	13	35 = G
	n	11	10	8	29 = Σn
	$\bar{y}$	1.00	1.10	1.63	1.21 = $\bar{\bar{y}}$
	$\frac{T^2}{n}$	11.0	12.1	21.1	44.2 = $\Sigma (\frac{T^2}{n})$

Analysis of Variance for Gravel Contents

Preliminary Calculations

Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	1,225	1	29	42.2
Sample	--	-	--	44.2
Observation	--	-	--	49.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	2.0	2	1.0	5.55
Within Sample	4.8	26	0.18	
Total	6.8	28		

The critical F value for 2 and 26 degrees of freedom is 3.3690 at the 5% confidence level so the hypothesis that the three means are equal is rejected and Duncan's New Multiple Range Test is applied.

Duncan's New Multiple Range Test for Gravel Content

9	Gravel Contents	Difference	Sig Stud. Range	ISR	SSR	Conclusion
3	(>50) - (0-20)	0.63	3.06	1.30	0.43	Significant
2	(>50) - (20-50)	0.53	2.91	1.23	0.41	Significant
2	(20-50) - (0-20)	0.10	2.91	1.23	0.38	Not sig.

Appendix F-2. Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Gravel Contents and Stoniness Classes

Sites Used for Comparison of Cobble Contents and Stoniness Classes

S1; 0-5% Cobbles	5, 29, 43, 45, 46, 47, 74, 75, 102, 177, 182, 183, 199, 332, 334
S2; 0-5% Cobbles	30, 73, 98, 99, 100, 101, 104, 105, 227, 264, 273, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 297, 299, 303, 305, 308, 350, 351, 390
S2; 6-10% Cobbles	117, 204, 287, 292, 300, 301, 304, 355, 363, 373, 378, 387, 389, 392, 393, 394, 395, 396, 398, 412
S3; 0-5% Cobbles	58, 268, 274, 359, 377, 420
S3; 6-10% Cobbles	356, 388, 400, 413

Stoniness Content and Cobble Results

Stoniness and Cobble Contents		S1;0-5	S2;0-5	S2;6-10	S3;0-5	S3;6-10	Combination
Observations (Responses)	1	13	29	16	2	-	
	2	-	-	4	4	4	
	3	-	-	-	-	-	
	4	-	-	-	-	-	
	5	-	-	-	-	-	
	T	13	29	24	10	8	84 = G
	n	13	29	20	6	4	72 = $\sum n$
	$\bar{y}$	1.00	1.00	1.20	1.67	2.0	1.17 = $\bar{\bar{y}}$
	$\frac{T^2}{n}$	13.0	29.0	28.8	16.7	16.0	103.5 = $\sum(\frac{T^2}{n})$

Analysis of Variance for Stoniness and Cobble Contents

Preliminary Calculations

Type of total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	7,056	1	72	98.0
Sample	--	-	--	103.5
Observation	--	-	--	108.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	5.5	4	1.375	20.5
Within Sample	4.5	67	0.067	
Total	10.0	71		

The critical F value for 4 and 67 degrees of freedom is 2.5161 at the 5% confidence level so the hypothesis that the five means are equal is rejected and Duncan's New Multiple Range Test is applied.

New Multiple Range Test for Stoniness and Cobble Contents

g	Stoniness and Cobble Content	Difference	Sig Stud. Range	ISR	SSR	Conclusion
5	(S3,6-10)-(S1,0-5)	1.0	3.14	0.81	0.33	Significant
4	(S3,6-10)-(S2,0-5)	1.0	3.07	0.79	0.30	Significant
3	(S3,6-10)-(S2,6-10)	0.8	2.97	0.77	0.30	Significant
2	(S3,6-10)-(S3,0-5)	0.33	2.82	0.73	0.33	Not sig.
4	(S3,0-5)-(S1,0-5)	0.67	3.07	0.79	0.28	Significant
3	(S3,0-5)-(S2,0-5)	0.67	2.97	0.77	0.24	Significant
2	(S3,0-5)-(S2,6-10)	0.47	2.82	0.73	0.24	Significant
3	(S2,6-10)-(S1,0-5)	0.20	2.97	0.77	0.19	Significant
2	(S2,6-10)-(S2,0-5)	0.20	2.82	0.73	0.15	Significant
2	(S2,0-5)-(S1,0-5)	0.0				Not sig.

Appendix F-3. Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Wetness

Sites Used for Comparison of Wetness

Well drained 7, 8, 12, 13, 17, 34, 37, 40, 59, 62, 94, 108, 112, 115, 118, 122, 123, 124, 129, 131, 135, 140, 141, 145, 196, 197, 198, 225, 236, 243, 245, 259, 260, 261, 262, 263, 291, 296, 338, 339, 340, 344, 360

Moderately well drained, W. T. below 90 cm 32, 38, 39, 53, 54, 55, 132, 139, 142, 265

Moderately well drained, W. T. 50-90 cm 24, 26, 91, 93, 120, 125, 127, 133, 368, 371, 372

Imperfectly drained 21, 23, 25, 31, 68, 126, 128, 136, 137, 138, 144, 154, 155, 306, 318, 324, 325, 326, 327

Poorly drained 10, 33, 314, 315, 316, 317, 328

Wetness Results

Wetness	Well	Mod Well >90	Mod Well 50-90	Imperfect	Poor	Combination
1	20	3	1	2	-	
2	20	5	7	12	3	
3	3	2	3	4	1	
4	-	-	-	1	1	
5	-	-	-	-	2	
T	69	19	24	42	23	177 = G
n	43	10	11	19	7	90 = Σn
$\bar{y}$	1.60	1.90	2.18	2.21	3.29	1.97 = $\bar{\bar{y}}$
$\frac{T^2}{n}$	110.7	36.1	52.4	92.8	75.6	367.6 = $\Sigma(\frac{T^2}{n})$

Analysis of Variance for Wetness

Preliminary Calculations

Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	31,329	1	90	348.1
Sample	--	-	--	367.6
Observation	--	-	--	413.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	19.5	4	4.875	9.19
Within Sample	45.4	85	0.53	
Total	64.9	39		

The critical F values for 4 and 85 degrees of freedom is 2.4927 at the 5% confidence level so the hypothesis that the five means are equal is rejected and Duncan's New Multiple Range Test is applied.

Duncan's New Multiple Range Test for Wetness

g	Wetness	Difference	Sig Stud. Range	ISR	SSR	Conclusion
5	Poor - Well	1.69	3.13	2.29	0.66	Significant
4	Poor - M. Well, >90	1.39	3.07	2.23	0.78	Significant
3	Poor - M. Well,50-90	1.11	2.97	2.16	0.74	Significant
2	Poor - Imperfect	1.08	2.82	2.10	0.66	Significant
4	Imperfect - Well	0.61	3.07	2.23	0.43	Significant
3	Imperfect - M.Well,>90	0.31	2.97	2.16	0.60	Not Sig.
2	Imperfect-M.Well,50-90	0.08	- Do	Not	Test -	Not Sig.
3	M.Well,50-90 - Well	0.58	3.97	2.16	0.52	Significant
2	M.Well,50-90 - Well,>90	0.28	2.82	2.10	0.65	Not Sig.
2	M.Well,>90 - Well	0.30	2.82	2.10	0.52	Not Sig.

Appendix F-4. Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Rockiness

Sites Used for Comparison of Rockiness

Rockiness 0	5, 42, 43, 45, 72, 73, 100, 101, 104, 105, 116, 117, 177, 181, 182, 183, 185, 189, 199, 213, 218, 219, 227, 237, 273, 375, 277, 278, 279, 281, 283, 284, 289, 292, 297, 299, 300, 301, 303, 304, 305, 308, 350, 351, 355, 362, 363, 364, 367, 370
Rockiness 1	78, 114, 203, 207, 217, 221, 246, 337
Rockiness 2	52, 64, 208, 209, 210, 215
Rockiness 3	79, 222
Rockiness 4	80, 81, 241

Rockiness Results

Rockiness		R 0	R 1	R 2	R 3	R 4	Combination
	1	42	3	1	-	-	
Observations	2	8	4	3	1	1	
(Responses)	3	-	1	1	1	2	
	4	-	-	1	-	-	
	5	-	-	-	-	-	
	T	58	14	14	5	8	99 = G
	n	50	8	6	2	3	$69 = \Sigma n$
	$\bar{y}$	1.16	1.75	2.33	2.50	2.67	$1.43 = \bar{\bar{y}}$
	$\frac{T^2}{n}$	67.3	24.5	32.7	12.5	21.3	$158.3 = \Sigma(\frac{T^2}{n})$

Analysis of Variance for Rockiness

Preliminary Calculations

Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	9,801	1	69	142.0
Sample	--	-	--	158.3
Observation	--	-	--	175.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	16.3	4	4.08	15.62
Within Sample	16.7	64	0.26	
Total	33	68		

The critical value for 4 and 64 degrees of freedom is 2.5200 at the 5% confidence level so the hypothesis that the five means are equal is rejected and Duncan's New Multiple Range Test is carried out.

Duncan's New Multiple Range Test for Rockiness

g	Rockiness	Difference	Sig Stud. Range	ISR	SSR	Conclusion
5	R 4 - R 0	1.51	3.14	1.60	0.67	Significant
4	R 4 - R 1	0.92	3.08		0.75	Significant
3	R 4 - R 2	0.34	2.98		0.76	Not Significant
2	R 4 - R 3	0.17	- Do	Not	Test -	Not Significant
4	R 3 - R 0	1.34	3.08	1.57	0.80	Significant
3	R 3 - R 1	0.75	2.98	1.52	0.85	Not Significant
2	R 3 - R 2	0.17	- Do	Not	Test -	Not Significant
3	R 2 - R 0	1.17	2.98	1.52	0.46	Significant
2	R 2 - R 1	0.58	- Do	Not	Test -	Not Significant
2	R 1 - R 0	0.59	2.83	1.44	0.41	Significant

Appendix F-5. Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Elevations

Sites Used for Comparison of Elevations

Sandy loam; $<$1,820 m ASL	72, 73, 75, 105, 218, 276, 277, 278, 281, 283, 284, 297, 300, 201, 304, 305
Sandy loam; $>$2,120 m ASL	378, 387, 390, 392, 393, 395, 396
Silt loam; $<$1,820 m ASL	7, 8, 12, 13, 17, 34, 37, 40, 59, 62, 94, 108, 112, 115, 118, 122, 123, 124, 129, 131, 135, 140, 141, 175, 196, 197, 198, 225, 236, 243, 245, 259, 260, 261, 262, 263, 291, 296, 338, 339, 340, 344, 360
Silt loam; $>$3,120 m ASL	156, 157, 158, 160, 382, 383, 386

Elevation Results

Texture and Elevation		SL $<$1,820 m	SL $>$2,120 m	SiL $<$1,820 m	SiL $>$2,120 m	Combination
	1	15	7	20	4	
Observations	2	1	–	20	1	
(Responses)	3	–	–	3	2	
	4	–	–	–	–	
	5	–	–	–	–	
	T	17	7	69	12	105 = G
	n	16	7	43	7	73 = Σn
	$\bar{y}$	1.06	1.0	1.60	1.71	1.44 = $\bar{\bar{y}}$
	$\frac{T^2}{n}$	18.1	7.0	110.7	20.6	156.4 = $\Sigma(\frac{T^2}{n})$

Analysis of Variance for Elevation

Preliminary Calculations				
Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	11,025	1	73	151.0
Sample	--	-	--	156.4
Observation	--	-	--	179.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	5.4	3	1.8	5.45
Within Sample	22.6	69	0.33	
Total	28.0	71		

The critical value for F with 3 and 69 degrees of freedom is 2.7464 at the 5% confidence level so the hypothesis that the four means are equal is rejected and Duncan's New Multiple Range Test is carried out.

Duncan's New Multiple Range Test for Elevation

g	Texture and Elevation	Difference	Sig Stud. Range	ISR	SSR	Conclusion
4	SiL;>2,120-SL;>2,120	0.71	3.07	1.76	0.59	Significant
3	SiL;>2,120-SL;<1,820	0.65	2.97	1.71	0.46	Significant
2	SiL;>2,120-SiL;<1,820	0.11	2.82	1.62	0.36	Not Sig.
3	SiL;<1,820-SL;>2,120	0.60	2.97	1.71	0.48	Significant
2	SiL;<1,820-SL;<1,820	0.54	2.82	1.62	0.31	Significant
2	SL;<1,820-SL;>2,120	0.06	2.82	1.62	0.51	Not Sig.

Appendix F-6. Analysis of Variance for Comparison of Site Slopes

Sites Used for Evaluation of Site Slopes

0 - 15%	72, 73, 75, 105, 284
16 - 30%	283, 297
31 - 60%	218, 276, 277, 278, 281, 300, 301, 304, 305

Site Slope Results

Site Slope		0 - 15%	16 - 30%	31 - 60%	Combination
	1	5	2	8	
Observations	2	-	-	1	
(Responses)	3	-	-	-	
	4	-	-	-	
	5	-	-	-	
	T	5	2	10	17 = G
	n	5	2	9	16 = Σn
	$\bar{y}$	1.0	1.0	1.11	1.06 = $\bar{\bar{y}}$
	$\frac{T^2}{n}$	5.0	2.0	11.11	18.11 = $\Sigma(\frac{T^2}{n})$

Analysis of Variance for Site Slope

Preliminary Calculations

Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	289	1	16	18.06
Sample	--	-	-	18.11
Observation	--	-	-	19.00

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	0.05	2	0.025	0.368
Within Sample	0.89	13	0.068	
Total	0.94	15		

The critical F value for 2 and 13 degrees of freedom is 3.8056 at the 5% confidence level, so the hypothesis that the three means are equal is accepted at the 5% confidence level.

Appendix F-7. Analysis of Variance for Comparison of Parent Materials

Sites Used for Comparison of Parent Materials

Outwash	1, 2, 45, 46, 47, 72, 73, 74, 75, 102, 105, 117
Alluvium	27, 29, 30, 43, 177
Till	5, 98, 99, 100, 101, 104, 182, 183, 218, 219, 227, 275, 277, 278, 279, 280, 281, 283, 287, 292, 294, 295, 297, 299, 300, 301, 303, 304, 305, 308, 350, 351, 355, 362, 363, 364, 367, 370

Parent Material Results

Parent Materials		Outwash	Alluvium	Till	Combination
Observations (Responses)	1	12	6	29	
	2	-	1	8	
	3	-	-	-	
	4	-	-	-	
	5	-	-	-	
	T	12	8	45	65 = G
	n	12	7	37	56 = Σn
	$\bar{y}$	1.00	1.14	1.22	1.16 = $\bar{\bar{y}}$
	$\frac{T^2}{n}$	12.0	9.1	54.7	75.8 = $\Sigma(\frac{T^2}{n})$

Analysis of Variance for Parent Materials

Preliminary Calculations

Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	4,225	1	56	75.4
Sample	--	-	-	75.8
Observation	--	-	-	83.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	0.4	2	0.2	1.42
Within Sample	7.2	53	0.14	
Total	7.6			

The critical F value for 2 and 53 degrees of freedom is 3.1789 at the 5% confidence level, so the hypothesis that the means of the three parent materials are equal is accepted.

Appendix F-8. Analysis of Variance for Comparison of Aspects

Sites Used for Comparison of Aspects

NE	17, 62, 243, 245, 261
E	12, 28, 34, 40, 42, 51, 59, 115, 171, 201, 236, 269, 271, 336
SE	35, 37, 196, 198, 202, 225, 260, 262, 263, 296, 338, 339, 344, 382, 386
S	7, 131, 175, 197, 223, 226, 228, 229, 230, 231, 259, 361, 369
SW	140, 141, 156, 158, 160, 340, 383
W	94, 122, 123, 157, 330, 331

Aspect Results

Aspects		NE	E	SE	S	SW	W	Combination
Observations (Responses)	1	1	7	3	7	4	3	
	2	4	5	9	5	2	2	
	3	-	3	2	-	1	1	
	4	-	-	-	-	-	-	
	5	-	-	-	-	-	-	
	T	9	26	27	17	11	10	100 = G
	n	5	15	14	12	7	6	59 = Σn
	$\bar{y}$	1.80	1.73	1.93	1.42	1.57	1.67	1.69 = $\bar{\bar{y}}$
	$\frac{T^2}{n}$	16.2	45.1	52.1	24.1	17.3	16.7	171.5 = $\Sigma(\frac{T^2}{n})$

Analysis of Variance for Aspects

Preliminary Calculations

Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	100	1	59	169.53
Sample	--	-	-	171.5
Observation	--	-	-	196.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	2.0	5	0.40	0.87
Within Sample	24.5	53	0.46	
Total	26.5	58		

The critical F value for 5 and 53 degrees of freedom is 2.3967 at the 5% confidence level, so the hypothesis that the six means are equal is accepted.

Appendix F-9. Analysis of Variance and Duncan's New Multiple Range Test for Comparison of Position on Slope

Sites Used for Comparison of Position on Slope

Lower 12, 28, 115, 166, 175, 196, 197, 198, 259, 260, 266, 269, 338, 339, 360, 361

Middle 34, 35, 37, 40, 42, 51, 59, 62, 124, 140, 156, 157, 158, 160, 201, 202, 223, 225, 226, 228, 229, 230, 231, 235, 243, 261, 262, 263, 271, 285, 296, 330, 369, 382, 383

Upper 94, 112, 123, 245, 331, 336, 386

Crest 7, 122, 131, 135, 141

Position on Slope Results

Position on Slope		Lower	Middle	Upper	Crest	Combination
	1	7	13	2	5	
Observations	2	8	21	2	-	
(Responses)	3	1	1	3	-	
	4	-	-	-	-	
	5	-	-	-	-	
	T	26	58	15	5	104 = G
	n	16	35	7	5	$63 = \Sigma n$
	$\bar{\bar{y}}$	1.63	1.66	2.14	1.00	$1.65 = \bar{\bar{y}}$
	$\frac{T^2}{n}$	42.3	96.1	32.1	5.0	$175.5 = \Sigma(\frac{T^2}{n})$

Analysis of Variance for Position on Slope

Preliminary Calculations				
Type of Total	Total of Squares	No.of Items Squared	No.of Observations Per Squared Item	Total of Squares Per Observation
Grand	10,816	1	63	171.7
Sample	--	-	-	175.5
Observation	--	-	-	196.0

Analysis of Variance

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F
Among Sample	3.8	3	1.27	3.63
Within Sample	20.5	59	0.35	
Total	24.3	62		

The critical F value for 3 and 59 degrees of freedom is 2.7612 at the 5% confidence level, so the hypothesis that the four means are equal is rejected and Duncan's New Multiple Range Test is carried out.

Duncan's New Multiple Range Test for Position on Slope

g	Position on Slope	Difference	Sig Stud. Range	ISR	SSR	Conclusion
4	Upper - Crest	1.14	3.08	1.82	0.75	Significant
3	Upper - Lower	0.51	2.98	1.76	0.56	Not Sig.
2	Upper - Middle	0.48	- Do	Not	Test -	
3	Middle - Crest	0.66	2.98	1.76	0.59	Significant
2	Middle - Lower	0.03	- Do	Not	Test -	
2	Lower - Crest	0.63	2.83	1.67	0.60	Significant

APPENDIX G

PARTICLE SIZE ANALYSIS RESULTS

The results of the particle size analysis are given below in Table G-1. These results show good agreement between the lab textures and field textures, with the exception of sites 1, 47, and 414. These sites have finer textures than estimated due to moderate contents of very fine gravel which give the impression of coarser textures. These sites exhibit good responses despite having silt loam textures, probably as a result of the stabilizing effect which these fine gravels have.

Table G-1. Particle Size Analysis Results.

Site	Laboratory					Field
No.	C.F.	S	Si	C	Texture	Texture
1	54	31	59	10	SiL	FSL
47	34	39	56	15	L	FSL
178	65	78	8	14	SL	VGSiL
340	61	29	51	20	SiL	SiL
348	40	34	56	10	SiL	GL
362	64	53	35	12	Sl-L	GL
371	0	20	73	7	SiL	SiL
386	43	25	67	8	SiL	SiL
414	53	39	49	12	L	FSL

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